May 2006

Adjustable Art Table Project

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Final Report

Adjustable Art Table

April 14, 2006

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Abstract

There is a significant need for height adjustable art tables in the United States and abroad. This type of table appeals to a wide variety of people due to its versatility; it can meet the needs of many different people. The table, designed for an art studio for people with developmental disabilities, fits the needs of this community and others. The ability to adjust in height makes it an attractive option for those who find regular tables too short for a wheelchair. Of course, every user desires a stable table that will not sway while in use. The aluminum frame is sturdy enough to prevent any unwanted movement. Previous art tables had been unstable and used an unreliable electronic adjustment mechanism. The art table that has been designed features two gas springs that have significant locking power for added stability. The gas springs also work in conjunction with two unibearing legs that allows the user to quickly and easily adjust the table without having to rely on any electrical components. This table improves upon previous shortcomings, in an efficient design that makes it a marketable and affordable necessity for every art studio.

1. Introduction

1.1. Background Information

The height adjustable art table is a project sponsored by the National Science Foundation (NSF), designed specifically for the artists at Passion Works Studio. The artists at Passion Works have various requirements which were delivered by the client coordinator, Dr. Brook Hallowell. In previous years, there had been NSF funded adjustable art tables that had flaws which were detrimental to the functionality of the table. It was also required that this project improve upon these previous tables' weaknesses. The primary purpose of the adjustable art table is to improve upon previous designs, and also to be competitive with the current market. There exist many adjustable art tables available, so the competition to make the most functional and affordable table is strong. The market still lacks however a table that would meet the specific needs for the people at the Passion Works Studio for an affordable price. Regardless of being NSF funded, the budget was a major concern. Parts in the design are only included if necessary; the design is the most efficient one that meets the needs of the artists and improves upon past designs.

1.2. Purpose

The design was made specifically for artists who may or may not use a wheelchair. Since the requirements for wheelchair users are more stringent it was necessary to design the table to meet these needs first, since a wheelchair accessible table is compatible for everyone. The purpose of the table is to design a table for artists who find conventional art tables to be difficult to use. Passion Works Studios provides opportunities for 135 adults with developmental disabilities, so it is necessary that the table can be shared by a wide variety of users. Many people might use the table during one day, so the height adjustment should not be cumbersome and time consuming. Also, due to the large number of users, there could be an array of different projects that the table could accommodate. With a tabletop made specifically for art work and table legs that can support heavy weights, the table can be used in many different situations.

1.3. Previous NSF Designs

Amongst NSF projects between 2001 and 2003, there have been approximately five tables designed for persons with disabilities. One was designed to attach directly to wheelchairs and did not serve as an art table (Buffalo 2002, p140). The table must allow users to wheel underneath the table to do a project. Another was designed to help children standing, so it attached to a walking device (Wright State 2003, p 388). This table will not make use of any walking devices. Also, in 2003 there was a table designed by Michigan Tech (p96) that incorporated a water tub so that the user could wheel up to the table and play with the water. This is a good design in that it is made specifically for wheelchair users, and it adjusts in height, but the purpose of the table is for water therapy and not for art. In 2001, students at Binghamton University designed (p51) a utility table for a person who needs a height adjustment for a wheelchair. The table looks more like a food tray since there are only two legs on one side, thus keeping the other three sides open (see picture in Appendix I). The table is adjustable with a cumbersome pin mechanism that requires much time and manipulation. It also poses some stability issues since it has just two legs, not to mention the table surface is not designed for art projects. In 2003, students at the University of Connecticut designed (p212) an art table specifically for Passion Works Studio. The table was made out a flimsy polyvinyl chloride (PVC) which proved too unstable while in use. For a more physical art project, the PVC was in adequate despite the structural support beams that it included. The table also featured a motorized height adjustment mechanism. The motors were run by battery in this instance, thus requiring running a power cord to the wall for recharging. In general, the requirement for the new adjustable art table is that there can be no electrical components involved; an electrical cord could pose a tripping hazard, and a battery would require maintenance. Simply put, a mechanical device is required for the adjustment mechanism. According to the picture for the 2003 adjustable art table, there is a cross-beam that extends from one end of the table to the other. This inhibits the user from wheeling completely underneath the table, thus rendering some of the table useless. As one could see in the picture, the exposed electrical wires create an unnecessary hazard and take away from the aesthetic value of the table. The table was designed specifically to improve upon these past flaws, and to add a competitive option to the list of available adjustable art tables.

1.4. Current Market

The current market is competitive in this field, but still could be improved. The affordable tables seem to be incompatible with wheelchairs. For example, the table called the Balt Easy, the cheapest adjustable table priced at $378, features a smooth plastic surface with round edges. The Balt Easy (see picture in Appendix I) also has a mechanical adjustment mechanism so it appeals to the less electrically savvy demographic. However there is a function limiting cross beam that restricts a wheel chair from moving completely under the table. The table is ineffective if the user cannot reach it. Airing on the expensive side, the Debcor table (see picture in Appendix I), priced at $535 boasts a height adjustable table, however it is not wheelchair accessible either due to a cross beam in the middle of the table. The mechanism uses a pin locking system that requires the user to remove the two pins, adjust the table height, and then replace the pins. This process depends greatly on the user's strength and motivation to adjust the table, and makes it difficult to perform multiple adjustments over the course of a day. Regardless if the user adjusts the table or not, there are still sharp corners that could injure the user. The corners on the designed adjustable art table would be rounded and the edges will be beveled. The most expensive art table, the Closet Masters (see picture in Appendix I), priced at $780 features a convenient inset table top for the user to fit into, but offers little leg room. The drawing surface looks smooth, and the ease of adjustment is good albeit electronic. The range of height adjustment is also out of the desired range, since it does not adjust between 24 and 42 inches. Taking all these flaws into account, most commercial tables are not tailored for persons of physical disabilities and who have wheelchairs, so it is difficult for them to use them comfortably. Some do not give enough leg room; the legs of the table could prevent the user from pulling all the way up to the table. The art table that will be built is unlike any other table on the market because it will easily accommodate wheelchair users through an easy-to-use adjustment mechanism. The adjustable art table will be unique because it will allow the user to easily move both underneath and above the table so that he or she can do work comfortably.

1.5. Scope and Methods

The design of the adjustable art table addresses each requirement through an efficient and easy to use design. The most important requirement is that a wheelchair should be able to fit underneath the table and still have adequate room for the artist's legs. This means that the table will have a minimum height clearance that it must exceed. The table features a clearance that is above that of a standard wheelchair, so the user can easily move underneath it. The tabletop is deep enough so that the user can fit comfortably underneath without any leg obstructions. Although there is a leg that is in the rear center of the table, it is far enough out of the way.

Second, the table is sturdy enough so that it does not wobble. This requirement, although obvious, is necessary because it contributes to the user's overall satisfaction with the table. The table is made out of a sturdy aluminum frame that is light weight and strong. The primary height adjustment gas springs that are in the sides of the table are able to withstand an excessive compressive force (in excess of 2,000 pounds). The secondary height adjustment mechanisms, the unibearings, are strong enough to stabilize the rear of the table in the event of a heavy load directly upon it. The table's frame comes into enough contact with the ground so that it does not rock.

An additional requirement is that the table's height adjustment mechanism not be electronic. Past art tables were electrically powered and required a battery. The battery involved excessive wires, and also required a regular maintenance to charge the battery. For a table that could be put in the middle of the room, an extension cord would pose a tripping hazard and also compensate its portability. The adjustable art table designed features no electric components; it uses strictly mechanical mechanisms. The combination of two gas springs with a unibearing has not been built before in previous designs, which makes this table unique.

1.6. Patents

Patents are issued in the United States by the US Patent and Trademark Office for a new invention that is created that is unique and serves a useful purpose such as improving upon a design. There are three types of patents that can be issued. They are utility, design, and plant patents. The adjustable table being built would fall in the category of design patents. This adjustable art table is going to be unique in its ease of usability, and the way it is designed to produce linear motion. There are a number of patents that have already been issued in the past by the US Patent and Trademark Office for adjustable art tables similar to the one being designed. The following are a few examples of what is already out there.

US Patent 6,701,853

This height adjustable table is supported by a scissor support mechanism which has a linear motion. The supports are parallel to one another with respect to the base. The table is raised and lowered using a sliding motion of the scissor supports. There are grooves in the base where the ends of the scissor mechanism can lock into place.

US Patent 6,102,808

This height adjustable table is designed for the purpose of billiards play. The table is lifted up and down by a transmission shaft running transverse to two parallel worm shafts at the front and rear ends underneath the table body. The transmission shaft is rotated using a motor. Upon rotation of this shaft the worm shafts will be synchronously driven to raise and lower the table.

US Patent 5,845,590

This height adjustable table has a foot rest built into its base assembly. The tabletop is raised and lowered vertically through a vertical position adjusting arrangement interconnected between the base assembly and tabletop. This arrangement includes a manual crank which the user can rotate which is interconnected with a drive sprocket which is then connected to a chain which extends to just underneath the tabletop. This design is comparable to the design of the adjustable art table at hand.

1.7. Map of Rest of Report

The adjustable art table provides an alternative for people who cannot use conventional art tables. However, it is an attractive option for anyone because of its stability, ease of use and safety considerations. Past NSF tables have been discussed, and currently available adjustable art tables were compared to each other and to the designed table. The table was designed through meeting a balance of affordable products that meet the general requirements. The specific design, which meets the aforementioned requirements, will be explained thoroughly.

2. Project Design

2.1. Design Alternatives

There were many aspects of the three designs that were positive, and others that could have caused problems during use. From the first design, the safety pins provided too much of a possible hassle for the user. It also leaves too much of a possible hazard if the pins were not inserted prior to use. Also, the distance between pinholes might make it difficult to exactly line up the holes. So, multiple adjustments might have been necessary to get the alignment right. The positive point of the first design was the setup. The theory of the lifting leg in the rear center with two safety legs appears very stable, and leaves no areas where excessive forces can be experienced in joints. Also, with the base extending along the back of the table instead of just the sides, there is side-to-side stability not found in the bases of the other designs.

The second design was very efficient in its adjustment mechanism, but the user would be required to put force either to push the table down or lift it up. For weaker users, this force might be harder to apply than if using a simple crank or handle. It also puts the artist at risk when lowering the table to their level. It is not desirable to be pushing the table down onto the artist. Even though there was an issue with the gas springs, they would still be usefully in the optimal design. The gas springs would be good safety legs because they can support excessive loads, are easily operated, and cannot be left inactivated. The gear rack system from the third design provides an excellent way to raise and lower the table. If only one gear rack is used and located in the rear center of the table it can be used to easily adjust the table with out direct application of force.

The tabletop from the third design was determined to be the best because wood can be unreliable. So, the laminate surface would provide the best surface possible. Also, the melamine tabletop was significantly cheaper than the other two tabletops. Also, the wheels and the height display were found to be unnecessary and were left out of the design.

2.1.1. Design One: Screw Jack

The first design was based around a screw jack positioned at the rear of the table. This would then be supported using two safety legs near the front of the table as seen in Fig. 1.

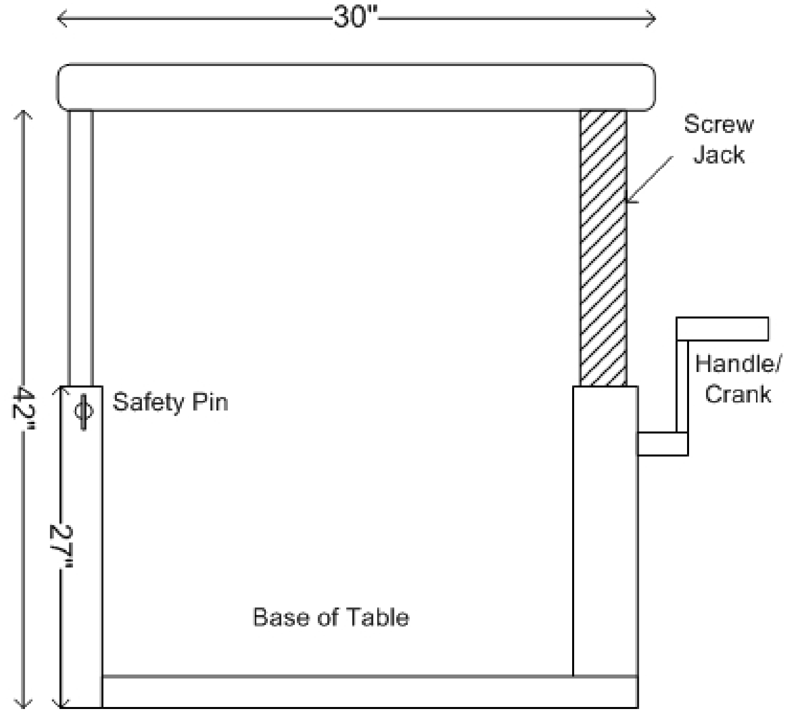

Figure 1: Side View of Design 1

This design would rely on the screw jack to perform all of the adjustments. The safety legs in the front would only be there to support the tabletop while the table is in use, and to ensure that the table is stable enough for the artist to use.

The tabletop will be made out of oak, and will be 30" by 48". This will provide a strong and easily manipulated tabletop. To increase the longevity of the tabletop an adhesive strip of laminate can be affixed to the surface of the oak. This will make the tabletop easier to clean and prevent the surface from being permanently marked or scratched.

Screw jacks are simple mechanical devices that employ two screws to raise or lower a load. The horizontal screw, called the worm, is turned using a handle that will extend out of the rear of the table. The worm then articulates with the vertical screw and causes it to move vertically. The screw jack that was going to be used for this design was manufactured by Nook industries (see References Section), and was designed to have the following specifications.

Table 1: Screw Jack Specifications

Gear Ratio	Capacity (Lbs)	Screw Diameter (In)	Turns of the Worm for 1" Travel	Torque to Raise 1 Lb (in-Lbs)
5:1	1000	0.625	10	0.0242

These specifications show that the screw jack would be able to support the weight of a person sitting on the table, or the weight of items stored on the table. Since the handle must be turned ten times for one inch of travel, the resolution of the table adjustment is very small. The table can be adjusted to a tenth of an inch. In order to raise one pound, the screw jack is designed to require .0242 in-lbs of torque. The handle used in this design is two inches long, so the force required from the user to raise the tabletop can be found.

$$T = F \times D$$
$$0.0242(Mass) = F \times 2$$
$$F = 0.0242 \times 45 \div 2 = 0.5445$$

So, in order to raise the table, only 0.5445 pounds of force are required from the user. The table is very easily adjusted when it is unloaded. If the table is loaded, either with art supplies or other items, the force required to raise the table will be greater. Even though the force will be greater, the table would still only require 6.05 lbs force to raise 500 lbs.

The two safety legs would be attached to the tabletop eight inches from the front edge of the table. These two safety legs would provide stability of the tabletop for when the artist leans on the front of the table, and for the situation in which someone would sit on the table. They would help to relieve the stresses at the mount between the screw jack and the tabletop. The safety legs would each be made of two cylindrical aluminum shafts. When the screw jack is used to adjust the table one of the cylinders will be able to move inside the other cylinder. When the table is in use, metal pins would be inserted to keep the legs in fixed positions. This is depicted in Fig. 2.

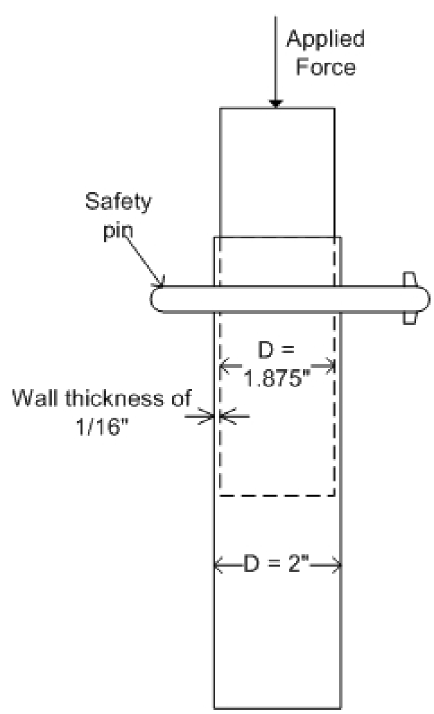

Figure 2: Aluminum Table Leg

The schematic for the handle was acquired from a source (see References Section). This is a basic handle that serves as a way to increase the mechanical advantage of turning the gear. The mechanical advantage comes about by having a handle which provides a bigger turning radius and therefore a bigger moment about that point. The bottom portion of the handle slides into the gear and the handle would stick out from the side of the table.

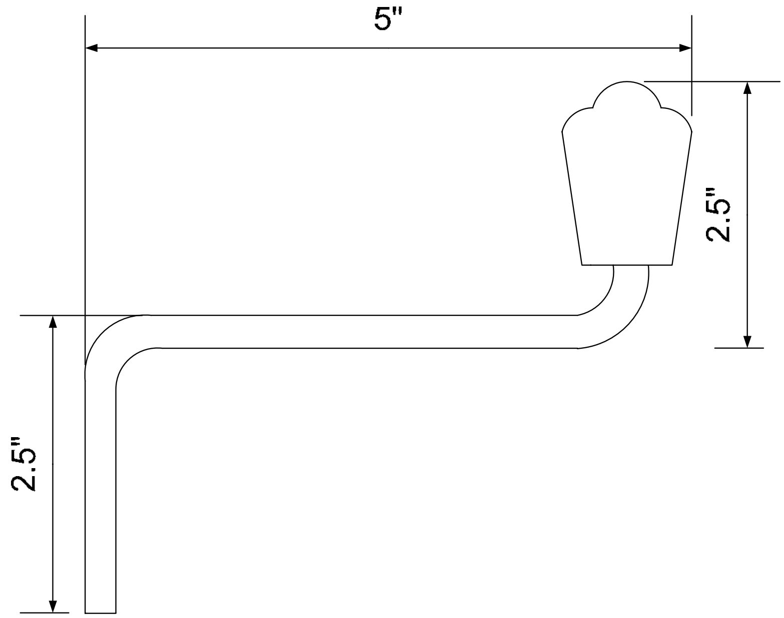

Figure 3: Handle Dimensions

An aluminum base that is made up of three four-inch beams supports the table. The three beams will have their edges matched up to three sides of the tabletop, the two sides and the rear. The three legs will be mounted between the tabletop and the base, and the base beams will be all welded together. The base is wide enough to allow a wheelchair to fit underneath, and the depth is far enough to allow adequate legroom. Also, because the base will extend all the way to the edges of the tabletop, there is no possible way for the table to tip.

The base is a very important component to the design of our art table. The base will be the basis for the strength and stability of the table. The base which will be integrated in this table design will be made out of a 6061-T6 aluminum flat bar. This bar will run along the sides as well as the entire back side of the table under the base. This bar will be oriented under the tabletop on the left and right sides of it. It will run the full thirty inches so that it is the same length as the tabletop. Another piece of the bar will be placed between the insides of these bars on the sides of the table. This bar will run the entire length of the back of the table. This will cause the base to run along the entire length of the tabletop when viewed from the back. This flat rectangular bar will add extra stability to the base. A figure of one of the flat bars which will be used for one of the sides of the base can be seen below.

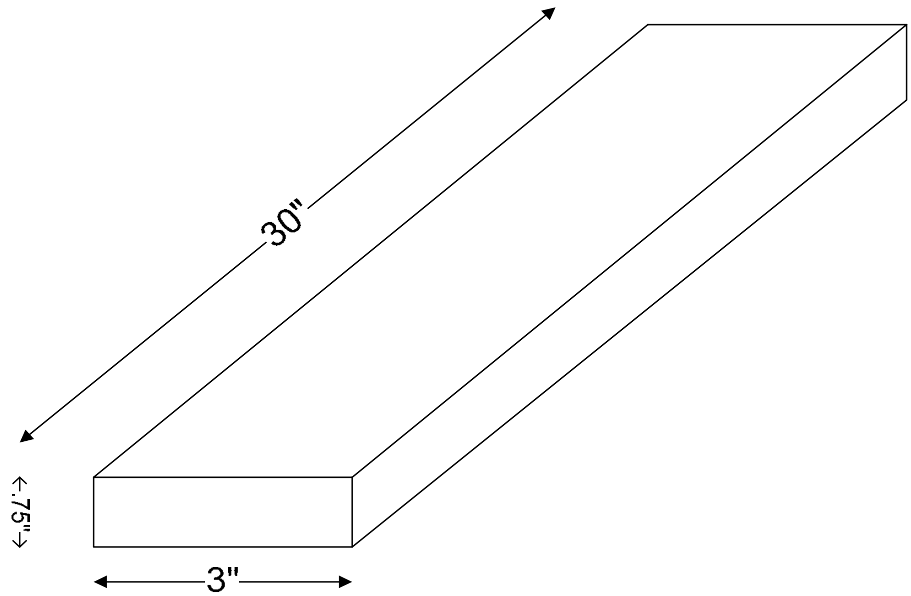

Figure 4: Table Base

This aluminum in general is lighter than most other metals such as steel, or brass. Aluminum is also very versatile and is very machinable. In the construction of this table, the base may have to be cut and fabricated in order to ensure certain parts of the table function properly. Aluminum is a great metal to do this with since it can be riveted, welded, brazed, or resin bonded. This metal has greater tensile strengths when compared to other metals. Aluminum also needs no protective coatings applied to it. The aluminum flat bar already comes finished. When looking into the costs for this design, aluminum is relatively less expensive when compared to other metals such as stainless steel. The only area where stainless steel would be more adequate to use would be the higher corrosion resistance it has over aluminum. This higher corrosion resistance would only be needed of the table were to be used outside where weather elements would increase the rate of corrosion. Since this table will be used indoors, the degree of resistance to corrosion of aluminum is negligible.

This design would be a good choice for a table, except for the fact that it requires the user to remove and reinsert the safety pins when adjusting the table. This leaves too much room for human error, where there could be serious injury to the user or damage to the table if the pins were not reinserted. Also, there could be problems adjusting the table due to needing to exactly line up the pinholes. Even though this makes adjustments more difficult, there are still some aspects of the table that were implemented into the final design that will be shown later.

2.1.2. Design 2: Gas Springs

This design relied on the use of two gas springs to raise and lower the table. Gas springs are devices that use nitrogen gas under pressure to raise objects. The gas is contained in a cylinder and kept under pressure by a moving piston. When the external forces applied to the piston produce a greater pressure than that in the gas, the gas spring is compressed. When the external forces are smaller than the force produced by the pressurized nitrogen, the gas spring expands.

The gas springs used for this design are rigid locking gas springs from Easylift of America. Rigid locking gas springs have a layer of oil in the cylinder that makes it harder to compress the gas, and therefore eliminates any bounce or give that might occur when load is applied. The locking mechanism comes from a hydraulic release incorporated into the cylinder that allows the spring to lock in any position, unlike the non-locking gas springs that only lock in the fully extended position. The two springs need to be pressurized to twenty-five pounds each, which is enough to balance the weight of the tabletop. To raise or lower the table, force must be applied to either the bottom or top of the tabletop. The locking component of the gas spring allows the table to withstand large amounts of force without moving. The specific gas springs can withstand approximately 2000 pounds of force without failing. This allows the table to stay stable when people are sitting on the table or when heavy objects are placed on the table.

The gas springs are operated using a parallel hydraulic release system. This uses liquid-filled hoses to connect a button to each gas spring's release. The single button operates both springs, so the springs will adjust evenly. The button will be located at the rear of the table, so an aide can operate the table and adjust the table to a comfortable height of someone in a wheelchair. This also keeps the button out of reach of the user, so there is no danger of accidental activation during use. The gas springs will be placed on each side of the table as seen in Fig. 5.

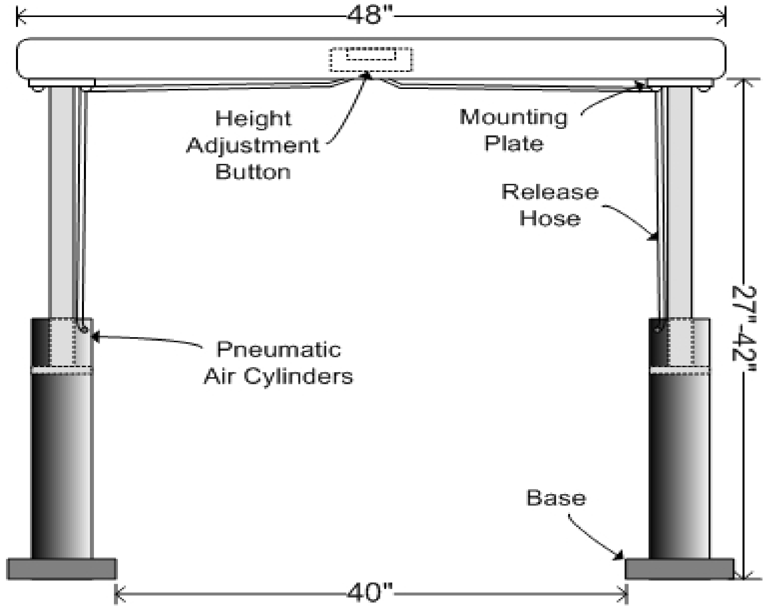

Figure 5: Rear View of Table

The base of this design is made of two beams of Douglas fir, one on each side of the table. This particular wood is very stable, and its versatility makes it a good choice for the base. It also makes it easy to attach wheels to the back of the base. This allows for portability without sacrificing stability. To move the table, the user must tip the table backwards onto the wheels, and push the table. Furthermore, this setup allows for more legroom and a more comfortable experience due to the absence of a rear leg and base. Again, the base extends to the ends of the tabletop to prevent tipping as in the first design.

For this design, the tabletop is a laminate art tabletop. The interior of the table is compressed particle board, which is coated with Formica. This makes the tabletop non-porous, smooth, and easily cleaned. Furthermore, the tabletop has soft, rubberized edges to ensure the safety of other artists in the studio. Attached to the tabletop will be both the hydraulic release and a height display. The height display is the Zircon Sonic Measure height sensor. It measures the distance from the tabletop to the floor by emitting ultrasonic wave and determining the distance based on when they are rebound back to the device. This would be beneficial to the user because it would allow them to quickly adjust the table to a known preferred height. So, the table would not need to be adjusted to a person, the table could be set up for specific users in advance.

The tabletop used in this design should be able to meet the specifications of the Passion Works artists as well as for anyone who would like to draw on it. The tabletop is going to weigh 28 pounds. This is a light weight when compared to other tabletops on the market. With having a lighter tabletop, it will be that much easier for the tabletop to be raised and lowered. The edges of the tabletop should be smooth to prevent injury to the user. The surface should also be very smooth, as it will be a drawing surface. The tabletop surface should also be easy to clean since some art materials may be spilled onto it. The tabletop used in this design will be from made by Safco. Its dimensions are 30 in. X 42 in. X 0.75 in. Since the width is 42 inches, this provides any user who is sitting in a wheelchair to have a comfortable full range of motion since maximum wheelchair widths are 35 inches. The width of the tabletop should not be out anyone's drawing range while it is in use, otherwise this would be a waste of material. The depth of the tabletop is 30 inches. This will provide plenty of arm extension for any user since the shoulder to arm length of a person 6 feet 5 inches tall when fully extended is about 30 inches. The dimensions of the tabletop can be seen in Figs. 8 and 9, and a three-dimensional view of the tabletop can be seen in Fig. 12.

Many of the artists who will be using the table at Passion Works will be in wheelchairs, so it is very important that the table accommodates all wheelchair types. The standard wheelchair is 26" wide and has a seat height of 21". This standard width would accommodate most of the wheelchairs on the market, but there are some exceptions that would require a larger width for the table. There are wheelchairs made for the obese, which have widths of 35". Therefore, the width of the space between the bases must be at least 36". This chair also has a depth of 20", so the shaft extending across the back of the table should be at least 20" from the front of the table. The artist's torso takes up anywhere from 5" to up to 15" of that depth, so there would be plenty of leg room for the artist if the shaft is locate approximately 25" back as in our design.

The surface of this tabletop will be that of laminated white melamine material. The inside of the tabletop is made from a plastic fiber, which is compressed cross-linked polymer. The melamine surface is made by mixing melamine powder with other substances, including an aqueous formaldehyde solution. This solution forms a resin which is also known as an adhesive which is added to the outside of the chip board. This resin is then processed further to make the laminate surface for the tabletop. This laminate surface has many good qualities and advantages which our clients will find in the tabletop surface. The melamine laminate surface is extremely durable and resistant to heat. This surface is also scratch and moisture resistant. This increases the lifetime of the tabletop over others since it will not get scratched up and soiled if water or other liquids are accidentally spilled on it. With the surface being moisture resistant, this also makes the tabletop very easy to clean. When looking into electrical conduction, the melamine surface is electrically insulating. Electricity could not be conducted from one side of the surface to another. This is just another extra safety feature that the melamine surface provides. With all the properties of the tabletop taken into account, it is apparent that this tabletop will provide the user with the maximal comfort as well as minimal maintenance.

The support legs for the table are two locking gas springs. The springs are placed opposite each other near the front of the table, and the adjustment control is located at the rear of the table. In a gas spring, a piston is fitted inside a cylinder with nitrogen gas under a specified pressure. When a valve is opened, the piston is moved either up or down based on the external forces exerted on it. Standard gas springs will only lock in a position in the fully extended configuration, or if the external force is large enough in the fully retracted configuration. On the other hand, locking gas springs allow the spring to be adjusted to any length and locked in place. This is because a release lever is inserted in the cylinder; only when a control button is pushed does the release lever move to allow the piston to travel.

Both types of gas spring work based on the same physical principles. The force exerted by the gas through the piston rod is based on the surface area of the piston and the pressure of the gas.

$$Area = (\pi \times diameter) \div 4$$

$$Force = area \times pressure$$

There are two main types of locking gas springs, elastic blocking and rigid blocking. Elastic blocking springs are filled only with nitrogen gas, and when locked will give a bit when external forces are applied. This creates a bounce effect on the spring such as in computer chairs, where a person is cushioned as they sit down. The rigid blocking springs resist all movement once locked, which is achieved by including a compartment of oil in the cylinder in addition to the nitrogen gas. The oil is not as easily compressed as the nitrogen gas, so when the external forces are applied the spring remains securely in place.

The locking gas spring used for the table is a rigid blocking gas spring from Easylift. The spring is rigid blocking in the push-in direction, meaning that it will resist moving under larger compressive forces. The configuration of the locking gas spring is important in determining the blocking type of the gas spring. In the rigid blocking in the push-in direction the oil is located between the piston and the end of the cylinder, and the nitrogen gas is located behind the piston and a floating piston. The floating piston separates the gas from the oil without making a rigid boundary. The piston is able to adjust as normal when unlocked, but when locked the oil is uncompressible, and there will be no movement. In rigid blocking in the pull-out direction, the floating piston is between the piston and the end of the cylinder and the gas is between the floating piston and the end of the cylinder. The oil is located between the floating piston and the piston, blocking the piston from being pulled out in the locked configuration. The configuration of the rigid blocking in compression gas spring is depicted in Fig. 6. For these locking gas springs the material of the piston, rod, and cylinder are steel, with zinc plated steel connecters. The oil is hydraulic oil and the release levers are made out of stainless steel.

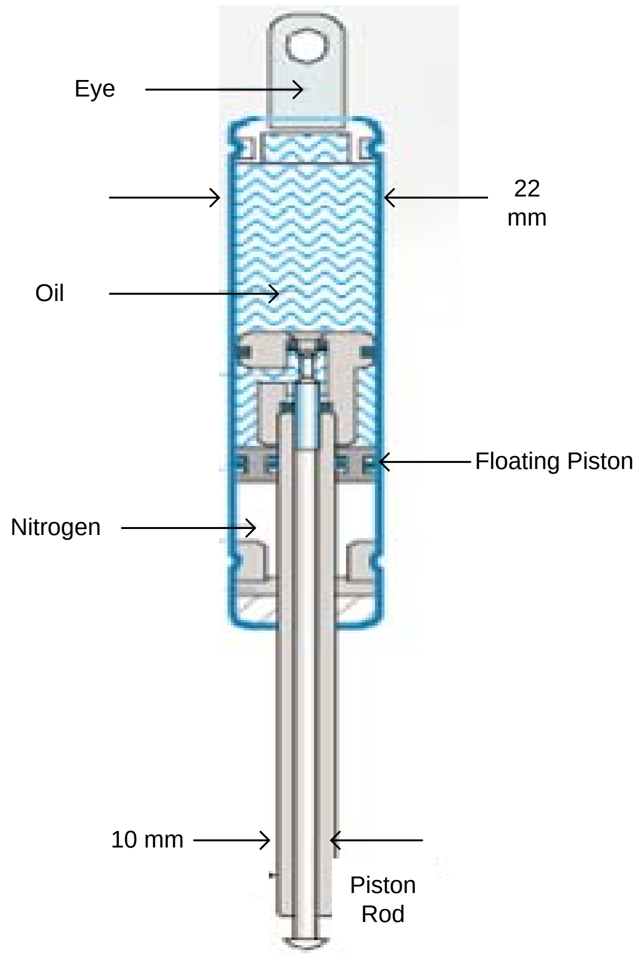

Figure 6: Rigid Blocking in Compression Gas Spring (See References Section)

The locking gas springs used for the table have specific dimensions and force requirements to operate the table. The specifications for the spring are presented in the table below.

Table 2: Gas Spring Specifications (See References Section)

Stroke Length	**Diameters of Rod/Piston**	**Length of Gas Spring (Fully Extended)**	**Blocking Force**
350 mm (13.78 in)	10/22 mm (0.4/0.87 in)	927 mm (36.5 in)	12000 N (~2,700 lbs)

The stroke length of the gas spring is the distance the spring can travel. The project specifications require that the table be able to travel between 27" and at least 40" off the floor, so the required stroke length is only 13". The stroke length of this gas spring allows for a little under an inch more travel, providing a larger range of adjustment than required. Each gas spring will be calibrated to exert a force equal to half the weight of the tabletop. This is enough to hold the table steady when the locking mechanism is released. When the release lever is locked into place the table will resist moving under applied forces, and maintain a stable surface for the user to complete art projects on. The blocking force of the locking gas spring corresponds to the amount of force that the gas spring can hold while locked without failing. This gas spring can withstand approximately 2,700 pounds, so the table itself can withstand approximately 5,400 pounds. This permits the user to store heavy objects on the table when not in use, and also ensures that the support legs will not fail if a heavy person sits on the tabletop.

In order to adjust the table the locking mechanisms must first be disabled. The mechanisms are controlled by a parallel hydraulic release system, which uses water to connect the control system to the springs. The hydraulic release system is the best system for operating the locking mechanism of the gas springs because of the ease of use. In other operating systems the mechanism is based around a lever or a handle requiring the user to exert force to operate it. The hydraulic release is based on a single button, which requires very little force from the user and is easily manipulated while adjusting the table. The table requires two gas springs as supports, so adjusting both at the same time would be difficult with other release systems. The hydraulic release system is the only system that can be configured into a parallel release. The parallel hydraulic release system allows for the integration of the controls for each gas spring into one control. The controls for both gas springs would be controlled by a single button, allowing one person to operate both with one hand. This also ensures that both gas springs are operated at the same time, taking away the risks of unequal adjustments and an uneven surface. Since hydraulic release systems are attached to the gas springs with hoses, the control can be attached to any location on the table. The release systems based on levers have limited range, and wouldn't be able to be put in the most optimal location. The parallel release system is depicted in the following figure.

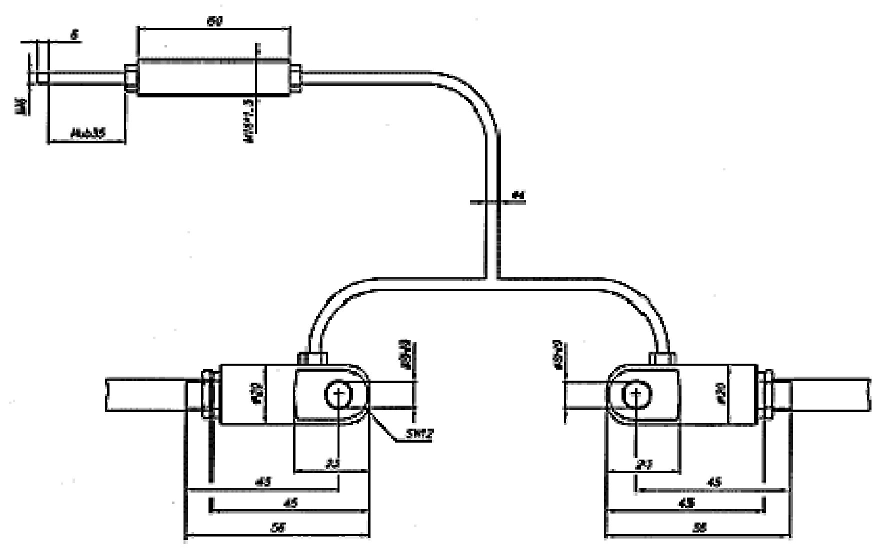

Figure 7: Parallel Hydraulic Release System (See References Section)

The release is going to be located on the rear of the table so that the button can be pressed and the handle turned at the same time. The hoses are going to run up the support legs and along the bottom of the tabletop, meeting in the back center of the table.

The safety of the users and bystanders is of utmost importance when dealing with a device such as this. The table is designed so that when it is locked in place, the pneumatics will stay in the same exact position as long as the button is not pressed. So that the button is not pushed accidentally, it will have a safety cover that must be opened so that the button is accessible. If the safety latch remains closed, then the button cannot be accessed and therefore the pneumatics will not be moved.

The main concern with the table is that it must be stable enough for the artist to work on it. The table can be placed under many different forces and it must resist tipping and breaking. Tipping could occur when large forces are placed on the edges of the table, such as someone sitting on the edge. The external forces acting on the table are depicted in Fig. 8.

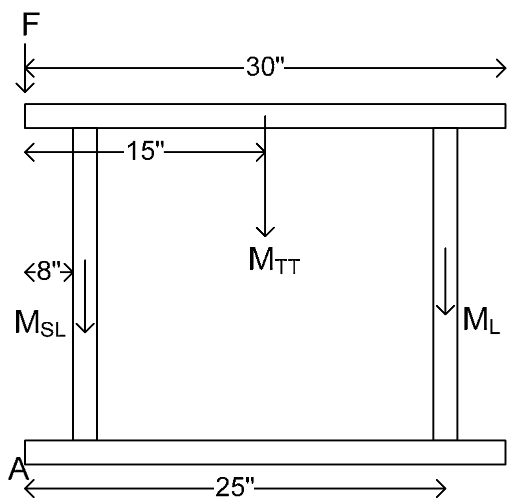

Figure 8: Free Body Diagram of Table

In this, the force M_{TT} is the mass of the table top and the forces M_L and M_{SL} are the masses of the adjusting leg and safety legs respectively. F is the load applied to the table. In order to tip the table the moment about point A must be positive, with the positive moment being defined as one that would cause a counter-clockwise rotation. The moment about point A is found using:

$$\sum M = F(0) - M_{TT}(15) - 2M_{SL}(8) - M_L(25).$$

Since this cannot be positive for any mass values, the table can never tip. This is due to the fact that the base of the table extends all the way to the edge of the tabletop, so no load could ever cause rotation around that point.

Even though the table will never tip, the loads applied will cause reactions in the joints between the legs and the tabletop and the legs and the base. For a load placed at the front of the table, as in Fig. 8, the free body diagram of the tabletop will be as shown in Fig. 9.

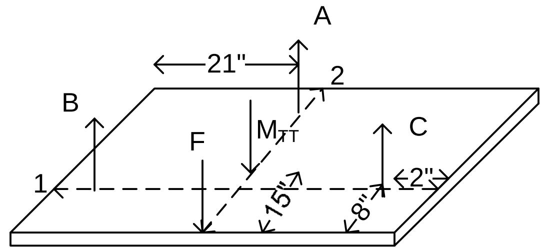

Figure 9: Free Body Diagram of the Tabletop with Front Force

The forces on the tabletop can be described by equations for the vertical forces and for the moments about lines through different forces.

$$\sum F_Y = 0 = A + B + C - F - M_{TT}$$

$$A + B + C = F + M_{TT}$$

$$\sum M_1 = 0 = F(8)) - M_{TT}(7) + A(17)$$

$$A = (7M_{TT} - 8F) \div (17)$$

$$\sum M_2 = 0 = B(19) - C(19)$$

$$B = C$$

$$A + 2B = F + M_{TT}$$

$$B = (25F + 10M_{TT}) \div (34) = C$$

The reaction forces at B and C are only equal if the load F is centered on the table. If the load is large enough, greater than $(7/8)M_{TT}$, then the lifting leg does not hold any of the load. Instead it has a negative force that holds the table down and doesn’t allow rotation. This does not mean that the lifting leg will never experience large reaction forces. If someone were to sit on the rear of the table directly over the lifting leg, as in Fig. 10, then there will be considerable forces in the leg and the joints.

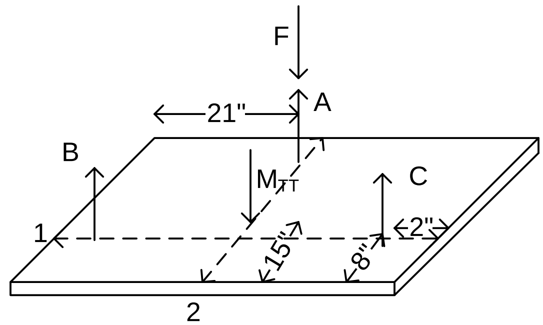

Figure 10: Free Body Diagram of the Tabletop with Rear Force

$$\sum M_1 = 0 = 17A - 17F - 7M_{TT}$$

$$A = F + (7/17)M_{TT}$$

$$\sum M_2 = 0 = 19B - 19C$$

$$B = C$$

$$A + 2B = F + M_{TT}$$

$$B = (5/17)M_{TT} = C$$

For this scenario there is very little force applied to the support legs and the load is carried almost entirely by the lifting leg. For the maximum load of 300 lbs, the lifting leg needs to have a strong enough locking mechanism so that it can support a total load of 311.5 lbs.

In the case where the load is directly over one of the support legs, the maximum possible vertical reaction for the leg is experienced. Since the load is not centered the support legs do not have equal reactions. For this scenario, the load is assumed to be concentrated directly over support leg C as in Fig. 11.

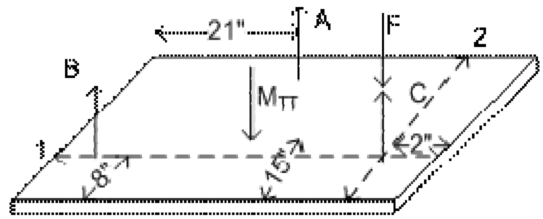

Figure 11: Free Body Diagram of the Tabletop with Side Force

$$\sum M_1 = 0 = 17A - 7M_{TT}$$

$$A = (7/17)M_{TT}$$

$$\sum M_2 = 0 = 19A + 38B - 19M_{TT}$$

$$B = (5/17)M_{TT}$$

$$A + B + C = F + M_{TT}$$

$$C = F + M_{TT} - (5/17)M_{TT} - (7/17)M_{TT}$$

$$C = F + (5/17)M_{TT}$$

Since the support legs are locking gas springs they will be able to hold approximately 2700 lbs while locked. So, with a maximum force of 300 lbs the legs will have no problem supporting the applied forces.

Horizontal forces can be applied to the table when moving it or by leaning on it, so the table needs to be reinforced in all directions. If a horizontal force is applied to the front of the table as if Fig. 12, it will be distributed among all the legs.

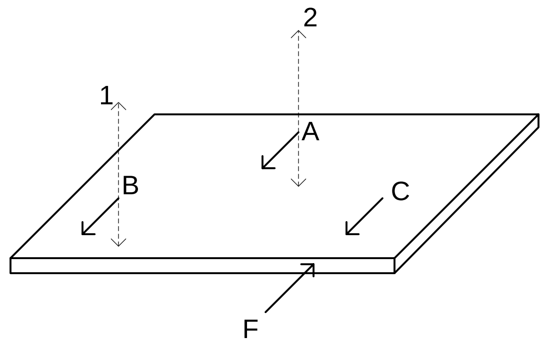

Figure 12: Free Body Diagram of the Tabletop with Horizontal Forces

$$A + B + C = F$$

$$\sum M_2 = 0 = 19B - 19C + 19F$$

$$C = B + F$$

$$\sum M_1 = 0 = 19A + 38C - 38F$$

$$A = 2F - 2C = 2F - 2(B + F) = -2B$$

The exact values of the reactions cannot be solved for, but it is safest to assume that all of the force is resisted by C. So, the reactions at A and B are equal to 0. This is the best method because it shows that the maximum necessary reactions are equal to the maximum applied force. So, all legs will be supported in such a way to oppose the maximum horizontal force in all directions. It can be assumed that the maximum horizontal force applied to the table will be around 100 lbs.

The support legs in the front of the table do not have any external forces applied to them, so the reactions between the legs and the tabletop are equal to the reactions at the base of the table. So, the base must be supported in the same manner as the tabletop. The lifting leg has a more complicated design than the supporting legs, but it should still transfer the forces to the base equally.

When lifting the table, the support legs will apply constant force while the gear rack lifts the table. The most likely setup for the pressure of each of the gas springs will be half of the mass of the tabletop. With this setup the two support legs will be able to hold the tabletop steady when engaged, and minimal force will be necessary to raise the rack.

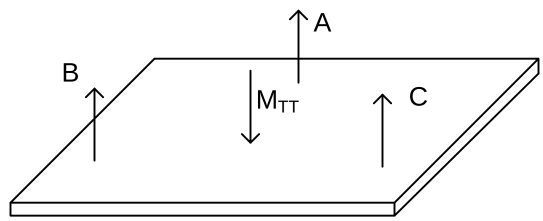

Figure 13: Free Body Diagram of the Tabletop During Lift

$$B = C = 0.5M_{TT}$$

$$\sum F_Y = 0 = A + B + C - M_{TT}$$

$$A + 2(0.5M_{TT}) - M_{TT} = 0$$

$$A = 0$$

The force A is the force required to hold the tabletop in place when the gas springs are engaged. To raise the tabletop, force A must be larger than 0. Very little force is required from the user to raise the table. For example, if 5 lbs were required to move the rack up and down smoothly the actual applied force in the handle is much lower. The diameter of the gear is 2.4" and the force of 5 lbs would be applied along the edge of the gear. So, the torque required to produce 5 lbs of force on the edge of the gear can be directly related to the force required on the 5" handle.

$$T = F \times r$$

$$T = 5 \times (2.4 \div 2) = 6 lbs \cdot in$$

$$F_{Handle} = T \div (r_{Handle}) = 6 \div 5 = 1.2 lbs$$

The forces from the gas springs make raising the table very simple, but there are problems associated with them. If the control for the gas springs were accidentally engaged the front end of the table would no longer be completely stable. If the table is unloaded at the time, the only consequence would be a moment in the lifting leg as shown in Fig. 14.

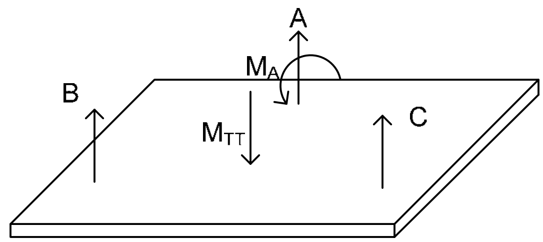

Figure 14: Free Body Diagram of the Tabletop after Engaging Gas Springs

$$B = C = 0.5M_{TT}$$

$$A = 0$$

$$M_A = (17)(0.5M_{TT}) + (17)(0.5M_{TT}) - (10)(M_{TT})$$

$$M_A = 17M_{TT} - 10M_{TT} = 7M_{TT}$$

If the table was loaded when the gas springs were engaged, the extra force could put the table in jeopardy of lowering in the front legs. If the force was at the front of the table, the moment will be much larger than when the table was unloaded.

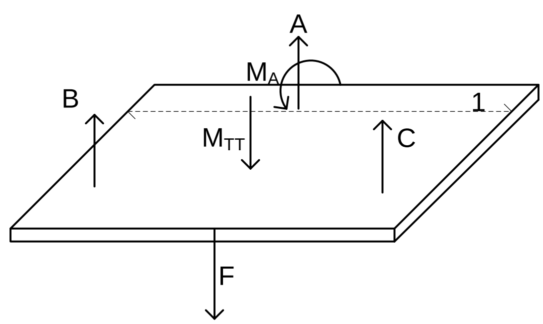

Figure 15: Free Body Diagram of the Tabletop with Front Loading and after Engaging Gas Springs

$$B = C = 0.5M_{TT}$$

$$\sum F_Y = 0 = 2(0.5M_{TT}) - M_{TT} - F + A$$

$$A = F$$

$$\sum M_1 = 0 = 25F + 10M_{TT} - 2(0.5M_{TT})(17) + M_A$$

$$M_A = -(25F - 7M_{TT})$$

The moment reaction at A is in the opposite direction, holding the table up instead of keeping it from rising as it was in the unloaded situation. If the load was directly over the lifting leg, the moments would be different as well.

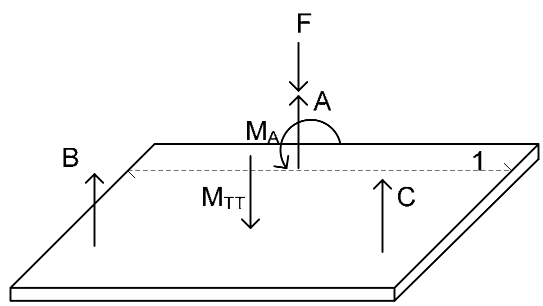

Figure 16: Free Body Diagram of the Tabletop with Rear Loading and after Engaging Gas Springs

$$A = F$$

$$B = C = 0.5M_{TT}$$

$$\sum M_1 = 0 = 2(0.5M_{TT})(17) - 10M_{TT} + M_A$$

$$M_A = 7M_{TT}$$

This moment is the same as when the table was unloaded. The lifting leg needs to be able to resist a maxim moment of $25F\text{-}7M_{TT}$. This is necessary to ensure that the table does not break and that anyone sitting on the table or sitting underneath it will be injured.

2.1.3. Design 3: Gear Rack

A gear rack is simple mechanical setup that employs a spur gear and a flat toothed bar. The spur gear, or pinion, is a standard circular gear and the rack can be considered a gear with an infinite diameter, making it essentially a flat bar. In this design the pinion is fixed, and the rack is moved vertically with each turn of the pinion. This raises and lowers the table, and because of the mechanical advantage of the gears there is very little force required from the user.

The design employs two rack and pinion systems, one on each side of the table and located near the rear of the table. A single shaft extends across the rear of the table to integrate the control of each rack into one crank handle. The gear shaft will be mounted on each side of the table onto square steel tubing. The rack would then move into and out of the tubing with the tabletop attached to the top end of the rack. The square tubing would then be mounted to aluminum bars for the base. The base would extend along the sides over the entire depth of the table to prevent tipping as in Design 2.

The tabletop is a white melamine laminate surface from Safco that is 42” by 30”. This surface is very light, only approximately 28 pounds, and is very durable. The table surface is laminate, so it makes cleanup very easy and also provides a smooth surface for the artists to work on. Melamine surfaces are commonly found on drafting tables, so they are very appropriate for art purposes.

The gear racks are located near the rear of the table, so there are stability issues for when forces are applied to the front of the table. To support the attachments at the gear racks, there are support beams on the sides of the table that run from near the center of the tabletop edge to the gear rack. The support beams are mounted securely to the tabletop, but articulate with the gear rack with a wheel. This allows the table to adjust with out being hindered by the support beams. These beams help to counteract moments around the gear rack mounting. The setup of the design can be seen in the following figures.

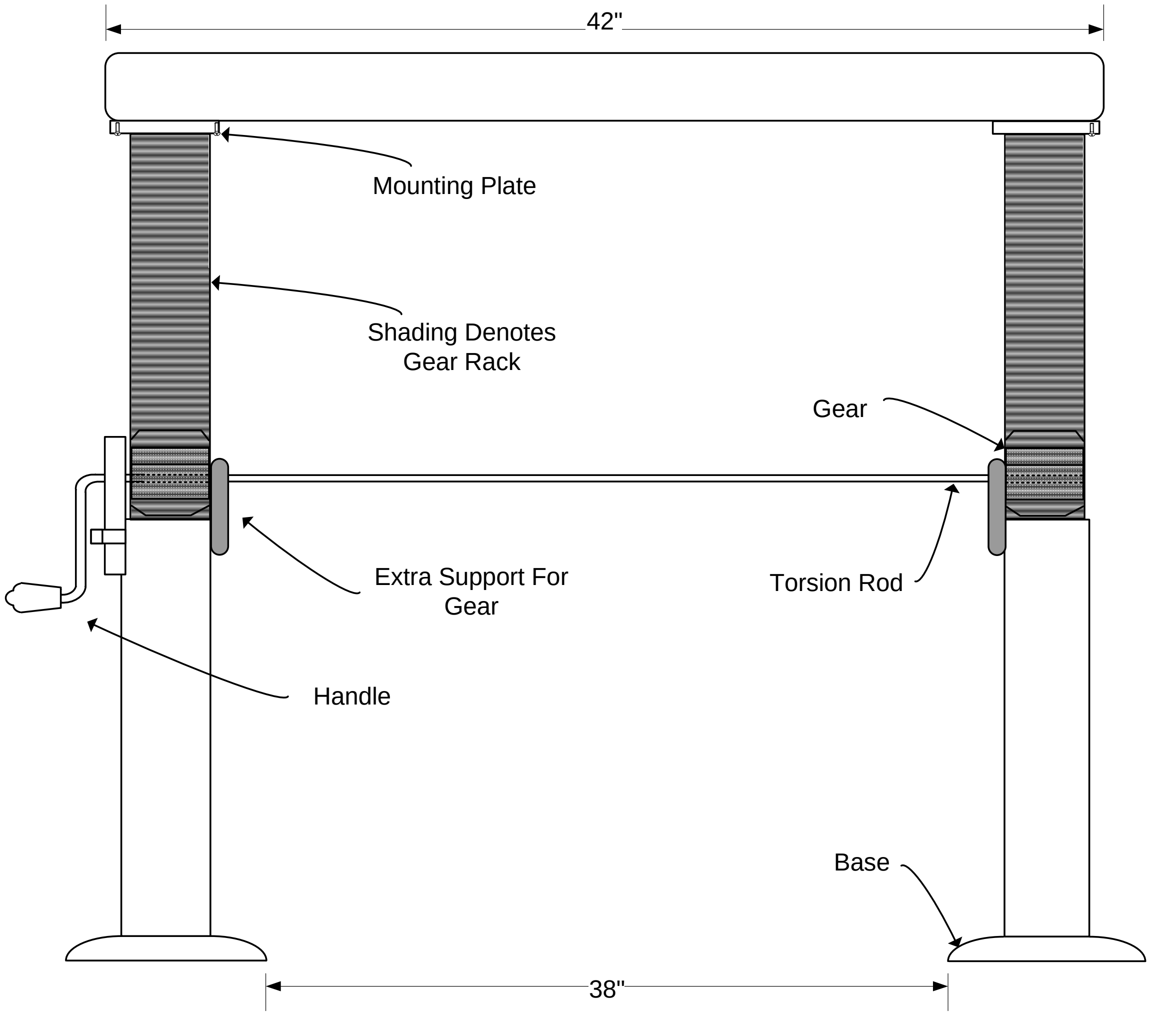

Figure 17: Rear View of Table

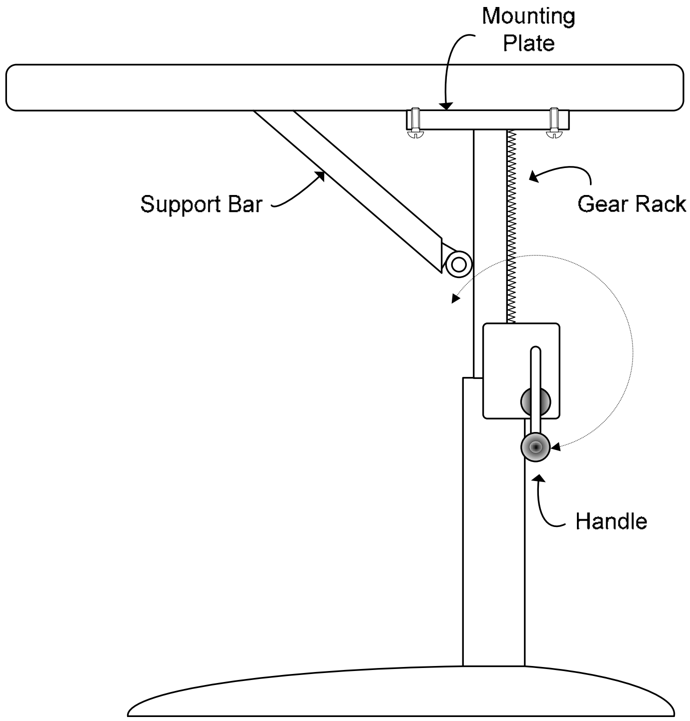

Figure 18: Side View of Table

The function of the support beams can be seen in the following equations based on the free-body diagrams in Figs. 19 and 20.

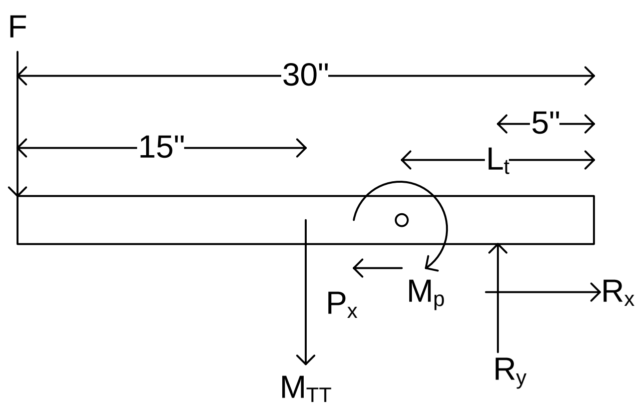

Figure 19: Free-body Diagram of the Tabletop

$$\sum M = 0 = F(25) + Mtt(10) - Mp$$

$$Mp = 25F + 10Mtt$$

$$\sum Fy = -F - Mtt + Ry$$

$$\sum Fx = -Px + Rx = 0$$

So, the horizontal reaction force at the gear rack mount is the same as the horizontal force on the support beam. By looking at the support beam, one can determine the horizontal force. The force F is the load applied at the front of the table; the force M_{TT} is the mass of the tabletop.

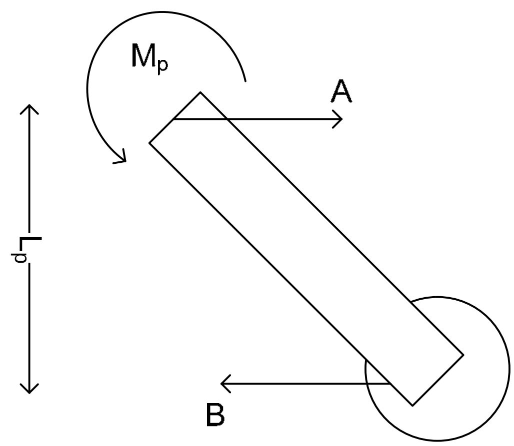

Figure 20: Free-body Diagram of the Support Beam

$$\sum M = 0 = Mp - B \times Lp$$

$$Mp = B \times Lp$$

So, $B = (25F + 10Mtt) \div Lp$

So, the forces caused by someone sitting on the table or by the artist during normal use will be transferred into horizontal forces that can be supported by the table legs. This happens because any vertical forces would cause the wheel to move, so only horizontal forces are possible on the support beam.

The pinion to be used in the design has a diameter of 2.4 inches, and the handle used is 5 inches long. This allows for the mechanical advantage of the gears to decrease the amount of force necessary to raise the table. The torque required from the gear shaft to raise the table and the force required on the handle can be found using the following equations.

$$T = F \times (2.4 \div 2) = 1.2\ F$$

$$F_{Handle} = 1.2F \div 5 = .24F$$

Since the tabletop is approximately 28 pounds and there are two legs, the force in each leg is 14 pounds. The force required from the user is:

$$F_{Handle} = 0.24(14) = 3.36 \text{ lbs}$$

So, the force required from the user is not excessive, and it makes it easy to perform numerous adjustments over the course of the day. This design also incorporated both wheels and the height display as in Design 2.

The previous figure shows what the gear would look like from the side of the table, looking outward, also looking through the gear support piece. The number of teeth on the gear, for this diagram, is arbitrary. Additionally, the shape of these teeth is not what will be used either. The figure provides a close up of how the gear and the gear rack would interact and also how the gear would be held together. The handle can be turned in either the clockwise or the counterclockwise direction as denoted by the double headed arrow. The safety latch is connected to the mounting plate to the side of the gear itself. The latch is spring loaded such that it will stay in contact with the gear rack as the table is being raised. The safety latch must be removed from the teeth so that the user could lower the table.

The adjustment mechanism for this design is a gear rack system, which relies on a handle to raise and lower the tabletop. The rack will be mounted to the tabletop and fitted to move up and down inside the square tubing. The gear shaft is mounted to the square tubing by two steel plates on each side of the leg, so the shaft will run through each plate with the gear in the middle. This supports and allows control of the gear while also allowing free movement of the rack into the tubing.

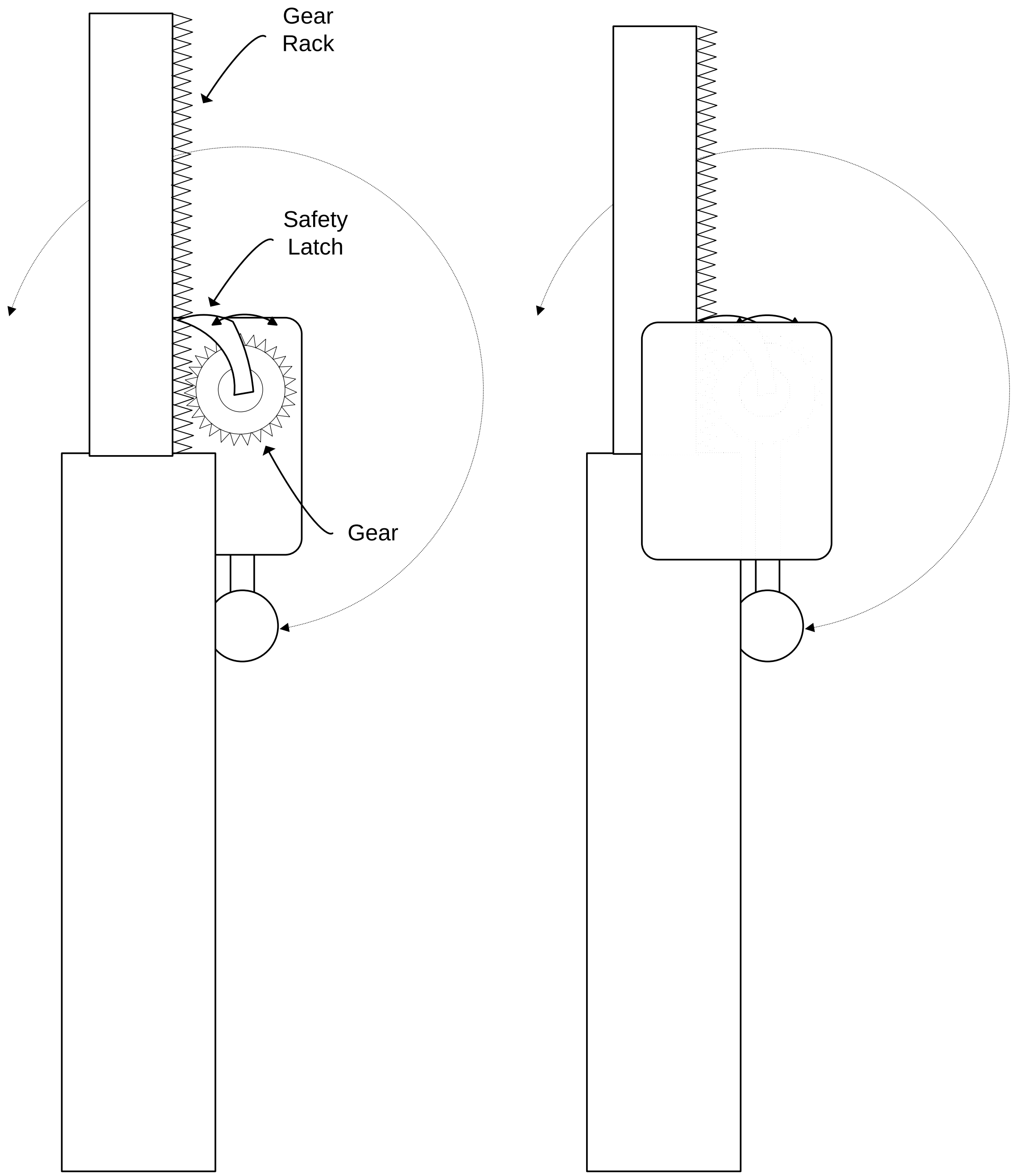

Figure 21: Side View Looking Through Mounting Plate

The rack and gear move together by interlocking teeth. The gear is rotated by a handle, which in turn causes linear movement of the rack. The setup is shown in the following figure.

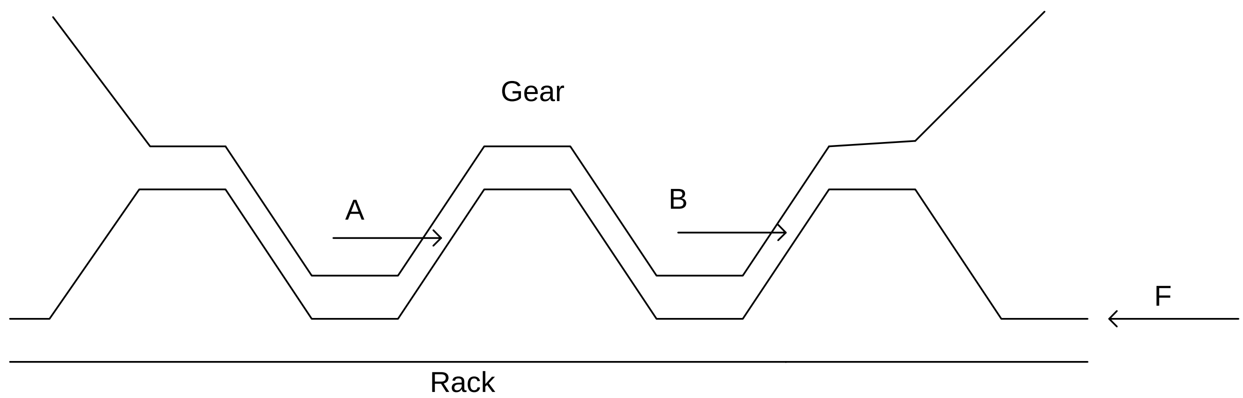

Figure 22: Gear Close Up

The force, F, is applied to the rack, and in order to raise the rack up, the gear must be rotated to apply the forces, A and B. In the design, F is the downward force of the tabletop and applied load. The gear used for the table has a diameter of 2.4 inches, so the torque required would be:

$$T = F \times (2.4 \div 2) = 1.2F$$

The handle used for turning the shaft is 5” long, so the force needed to provide the necessary torque is found by:

$$F = 0.6F \div 5 = 0.24F$$

The gear has a diameter of 1.2 inches, so the circumference of the gear is:

$$C = 1.2\pi = 7.54''$$

With each turn of the gear, or handle, the rack moves a distance of 7.54 inches. So, each tooth on the rack corresponds to a length of:

$$L = 7.54 \div 48 = 0.157''$$

When the table is stationary, there will be an extra piece to ensure that the gear and shaft do not rotate and allow the table to lower on its own.

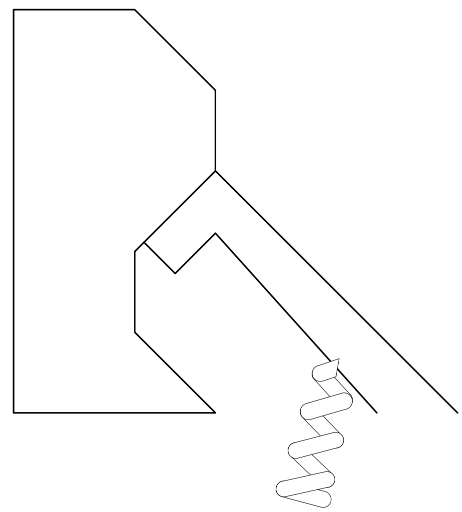

Figure 23: Safety Latch

In this, the latch is positioned in the groove between teeth and attached to the leg by a spring. When the table is raised the latch is dragged out of position by the next tooth, and then placed in the next groove by the spring. When the table is to be lowered, the latch must be removed. When the table is held steady, the shaft holds the rack in place and keeps the gear from rotating.

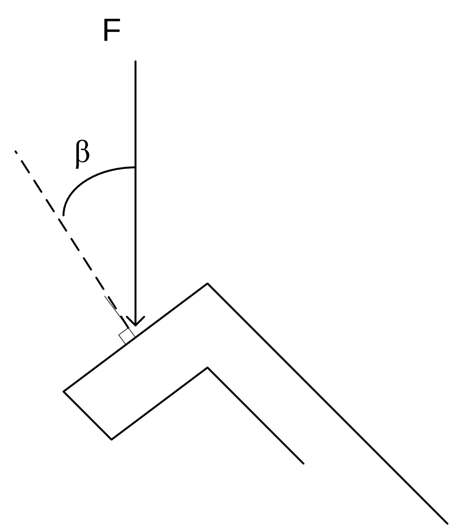

Figure 24: Forces Acting on Safety Latch

The force, F, is the force on the rack. Therefore, the bar will need to be strong enough to withstand the maximum forces applied to the table. It has been assumed that the maximum possible force applied to the table will be 311.5 pounds, so the joint where the latch is connected to the leg and the latch itself must be able to withstand that force.

When this is in use there will be less force on the gears. The overall forces on the table base and joints should be the same as when it is not in use, but the height will be kept constant without force being applied to the handle.

2.2. Optimal Design

2.2.1. Objective

The design that we decided on can be related to the second alternative design that was described in the above sections. The table adjusts using two gas springs positioned at opposite corners of the tabletop. These gas springs are charged to provide just enough force to slowly raise the tabletop, while requiring a small amount of force to lower the tabletop. The second alternative design had some flaws, which is why we decided to amend it for our optimal design. We felt that having the gas springs as the only legs would not provide enough stability for when large amounts of forces are applied to the edges of the table. We felt that the torque created by someone working on the table, or even worse sitting on the table, would be too great for the mounts we would be manufacturing. We decided that four legs would be necessary to provide the stability and safety that is expected from a quality art table. Four gas springs would be unnecessary to raise a tabletop as light as we have, so each of the two additional legs were made out of two pieces of aluminum with a sliding bearing in between them.

The bearings in the two non-lifting legs provide clean and smooth articulation between the two parts of each leg. If a person was going to use the table the corners with these legs would move up and down with all motions from the use due to the ease of articulation in the legs. This not only makes creating an art project difficult, but it also creates a serious safety hazard if too much load is applied at those corners. To solve this problem brakes were used on each of the bearings. These brakes utilize friction to hold the position of the table steady and to ensure that the table does not collapse onto a user.

In order to use the table, one must unlock the brakes on each of the two aluminum legs before doing anything. This allows the table to adjust and also prevent any harm from occurring to the gas springs or the joints of the table. The user must then activate the gas springs using the release button mounted to the side of the table. If the table is to be raised the user does not need to perform anymore work besides keeping the release button depressed until the tabletop reaches its desired height. In order to lower the table two people are required to adjust the table. This is because the size of the table makes it impossible for one person to generate enough force to lower the gas springs on the opposite side of the table. If one person stands at each end of the table little force is required from each user to gently lower the table into position. The release button must then be released and the aluminum legs locked before use. The step by step process can be better seen in the following block diagram.

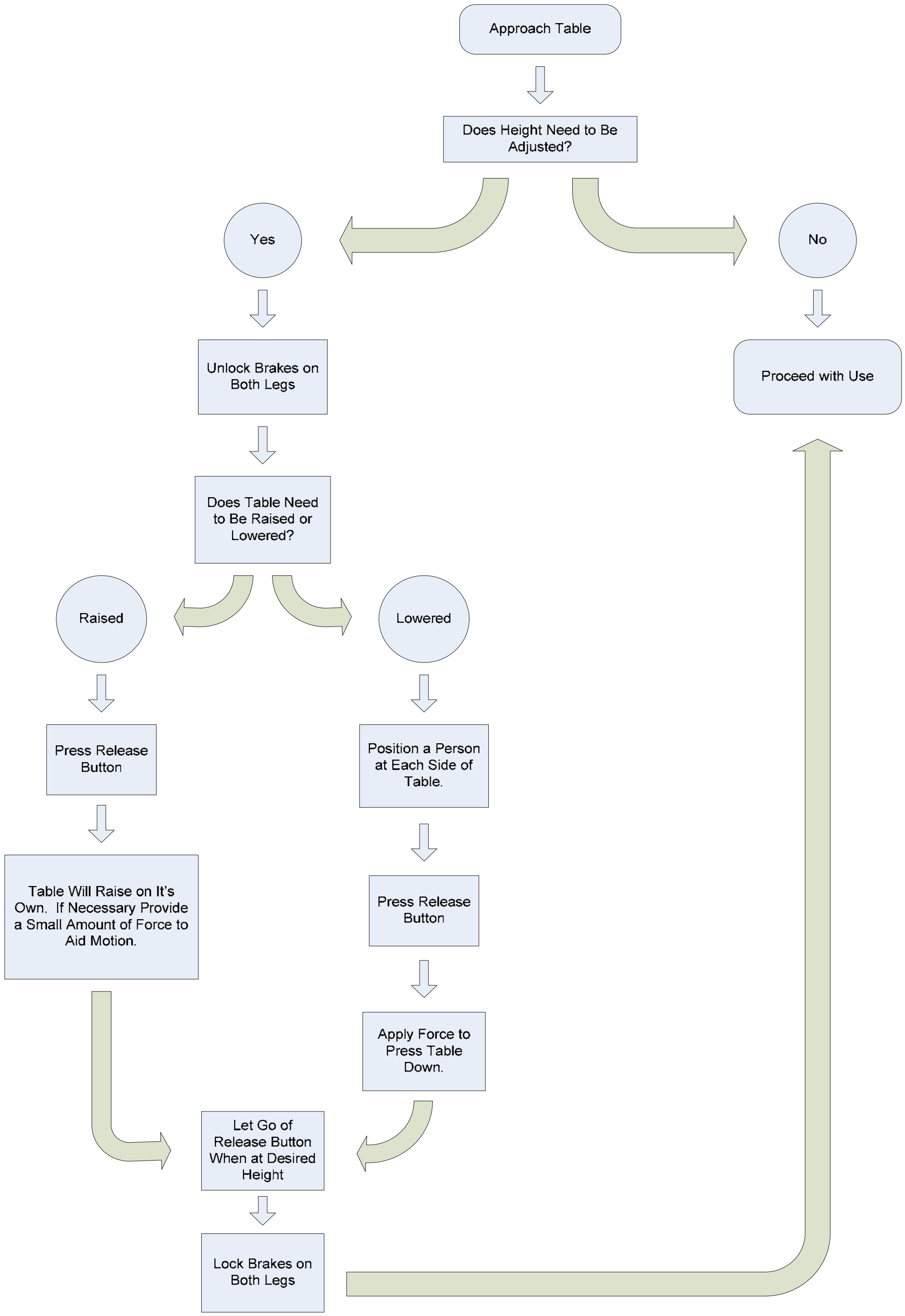

Figure 25: Steps for Operation

Additional changes were made from the alternate designs because our specifications changed after talking with a different client coordinator. We discovered that the table needs to be used by up to four people, not one like we were originally told. This meant considerable changes to our design. Luckily we were able to salvage most of the parts from our original optimal design and continue to use them. The one major change was the size of the tabletop that was required. Our original tabletop was not large enough, so we had to find a tabletop that was large enough to fit four people, but was also light enough so that our gas springs could still be used. We were able to find one, which will be explained in greater detail in the following sections. A diagram of the entire table can be seen below.

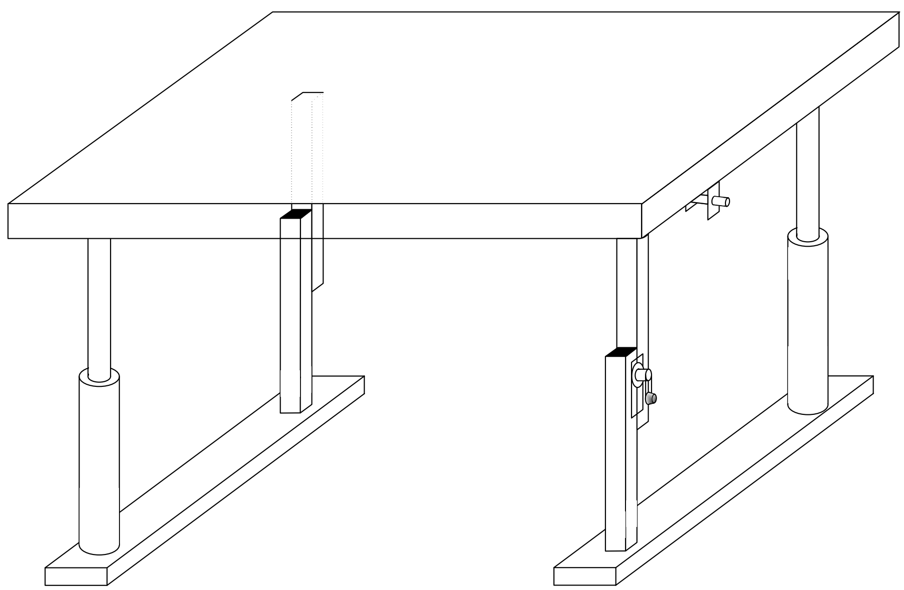

Figure 26: Diagram of Finished Table

2.2.2. Subunits

2.2.2.1. Tabletop

The tabletop used in this design should be able to meet the specifications of the Passion Works artists as well as for anyone who would like to draw on it. The tabletop is going to weigh 25 pounds. This is a light weight when compared to other tabletops on the market. With having a lighter tabletop, it will be that much easier for the tabletop to be raised and lowered. The edges of the tabletop should be smooth to prevent injury to the user. The surface should also be very smooth, as it will be a surface for drawing on.

The group decided to go with a table from Staples. The legs attached to the table were taken off since they were not going to be needed since the base was going to consist of 80/20 extrusions. The side frames needed to be unscrewed using a flat-head screwdriver. Once the side frame was removed, the cross-beams were no longer intact in between the two frame beams. Removing the side beams allowed the cross beam to be removed. Once the legs were detached, the side frames were put back into place with the appropriate screwdrivers.

The tabletop has dimensions of 72X30”. This longer tabletop is going to allow 2 people to sit comfortably on each side of the table. Each person would also have plenty of drawing space to meet his or her drawing needs. Since people would be sitting on both of the long sides of the table, no bars were able to be placed on the ground connecting the sides. This would impinge upon the artists’ amount of leg room. A diagram showing the tabletop dimensions can be seen in fig. 1.

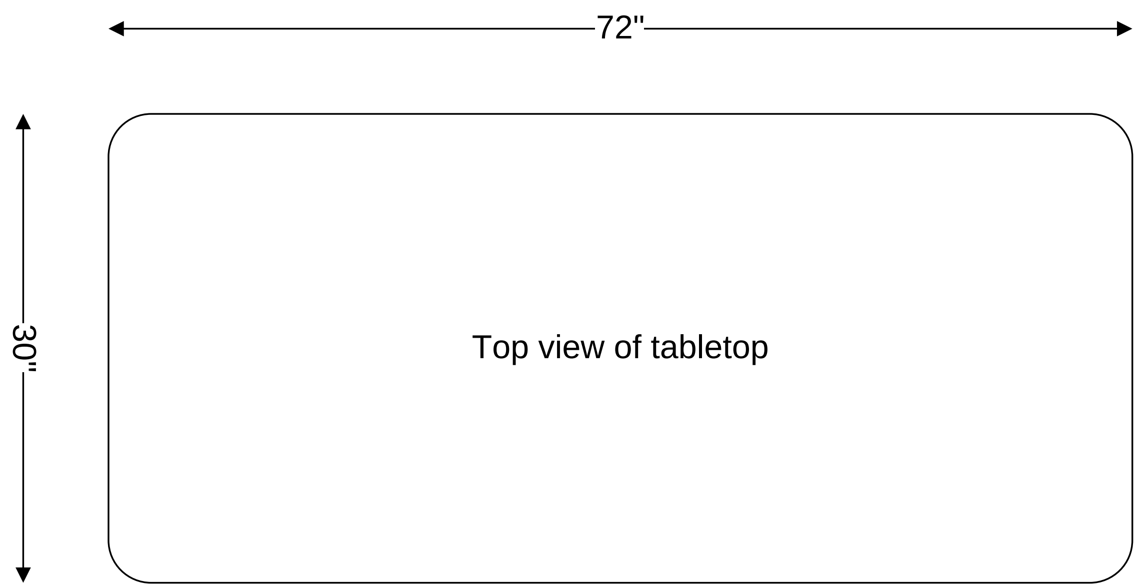

Figure 27: Dimensions of tabletop

This tabletop is made out of a plastic resin material. This type of material allows for the edges of the tabletop to be extremely smooth. This will prevent any sort of injury that may occur to the user or anyone that accidentally bumps into the table. This plastic material also allows for a smooth and easy to clean tabletop. If juice was spilled on the tabletop, the liquid would not be absorbed into it which could decrease the integrity of the tabletop. Since the tabletop is made of plastic, it is relatively lighter than other conventional tabletops out on the market. This will allow for relatively easier portability of the table.

A downfall to this tabletop is partly in fact to that it is so light. This tabletop will need a strong support between the two sides of it. For example, if someone decided to sit on the table directly in the center, it could possibly start to deform in that particular area if there was no support framing directly underneath. A solution to this problem will be discussed in the framing section. Luckily, the tabletop came equipped with long steel bars that attached underneath the tabletop on each of the long sides. A diagram of this can be seen in Fig. 28. These support beams are very strong and will help prevent the tabletop from trying to torque when it is raised. They will also reinforce the integrity of the tabletop if someone decides to sit anywhere between the two sides.

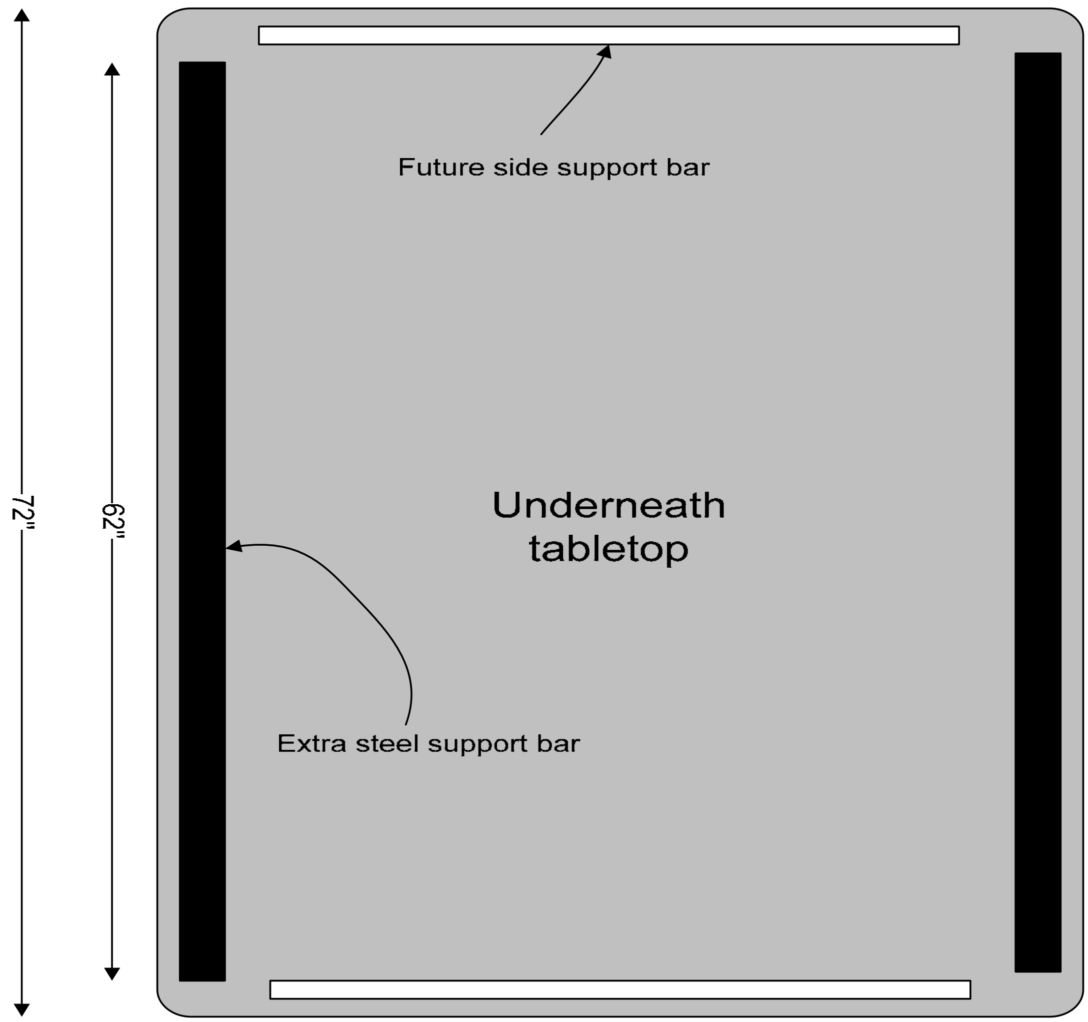

Figure 28: Steel support bars underneath tabletop

The tabletop is going to be the most frequently used piece of material from the design. Over time, it must be able to withstand various amounts of forces. The most common and strenuous force it will undergo would be someone sitting directly in the center. This would put the downward force furthest away from the sides. In order to figure out what amounts of force the tabletop could hold, a 3 point bend test was performed on it. This test can be demonstrated in Fig. 29.

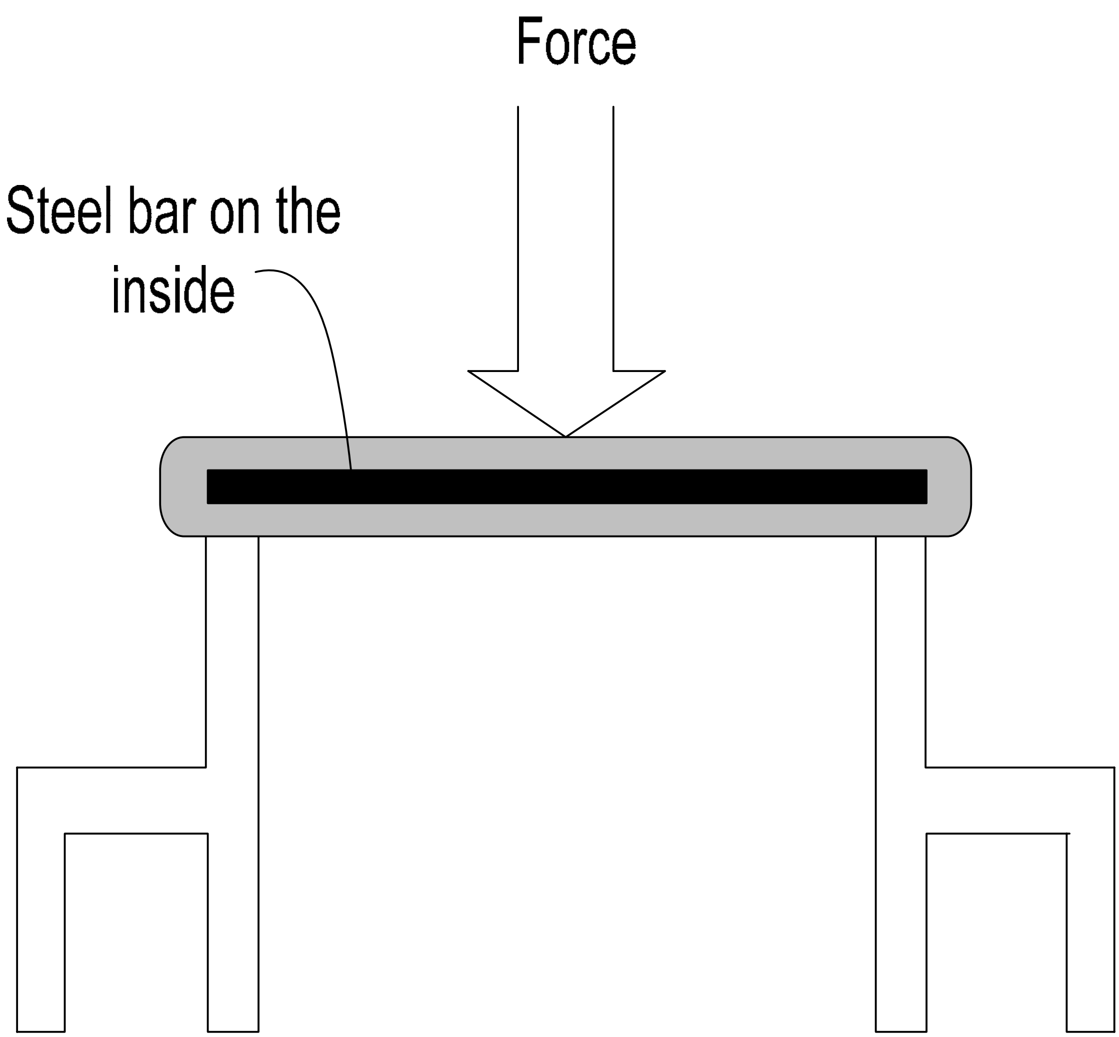

Figure 29: 3 point bend test on tabletop

The tabletop was placed in between two chairs which acted as supports on each of its sides. Next, various forces were put along the middle plane of the table furthest from each chair. The tabletop was able to withstand a large amount of force with minimal deflection. The table would not successfully hold an entire person. This was because the test was done without any of the upper framing attached underneath the tabletop. This upper framing will greatly strengthen the integrity of the tabletop. This will be talked about in greater detail in the next section.

With a larger 72x30 inch tabletop, it would be impossible for the hydraulic release to just be placed on one side and still control both gas springs. The dimensions for the hydraulic release had to be modified. A representative from Easylift was able to increase the lengths of the tubing so that it would reach both sides of the larger table. This will be discussed in greater detail in the gas springs section.

2.2.2.2. Framing

The framing is a very crucial piece in the stability of the table. The framing will affect how the table raises as well as how strong the table will be in certain areas. The frame design would also have to accommodate people sitting on each side of the table. There would also have to be no framing running between the sides along the ground. This would inhibit wheelchair users from using the table in a comfortable manner. The framing has to be distributed evenly along the entire table. It also must be cut exactly to specifications or else the table will not function properly.

All of the framing will be fabricated from 80/20 extrusion. The framing will consist of three parts made from the following size extrusions:

Upper framing	1X1" 1010 extrusion
Sliding Unibearing legs	1X1" 1010 extrusion
Base	1X3" 1030 extrusion

In order to minimize costs, an order for two 97" extrusions, as well as a 25" extrusion was placed. When the extrusions arrived, they had to be cut into their proper lengths in the machine shop. A diagram of how these extrusions were cut can be seen in Fig. 30 below. Each piece of extrusion will then be placed into its proper orientation to complete the frame setup.

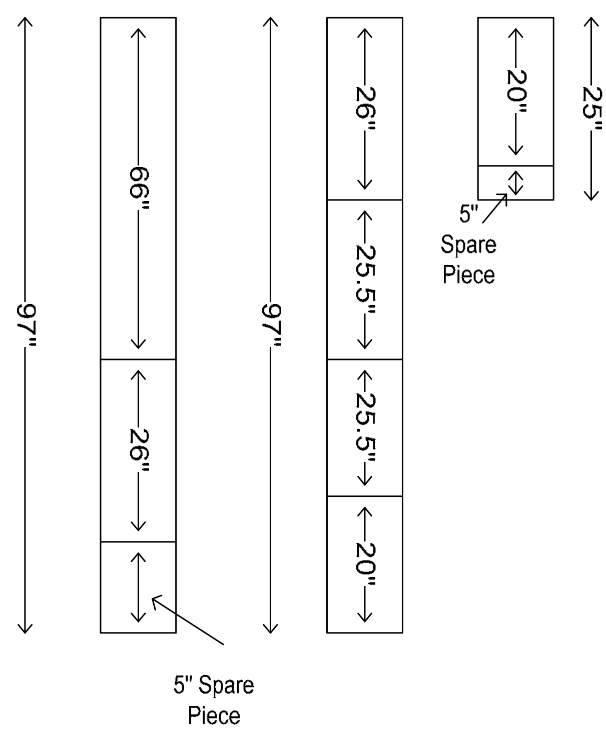

Figure 30: Dimensions required to cut 1x1" 80/20 extrusion

A preliminary design was constructed of how the framing setup would look when put together. This design can be seen below in Fig. 31. It should be noted that in this diagram, the gas springs are being considered part of the framing as well, since they will be acting as strong supporting legs. It can also be seen that this design fulfills all of the requirements that the framing setup needs. In this setup, the table will have 4 adjusting legs, a thick base platform, and a strong and centered upper framing attachment. With this frame design, two people who use wheelchairs will be able to situate themselves on each side and use the table comfortably.

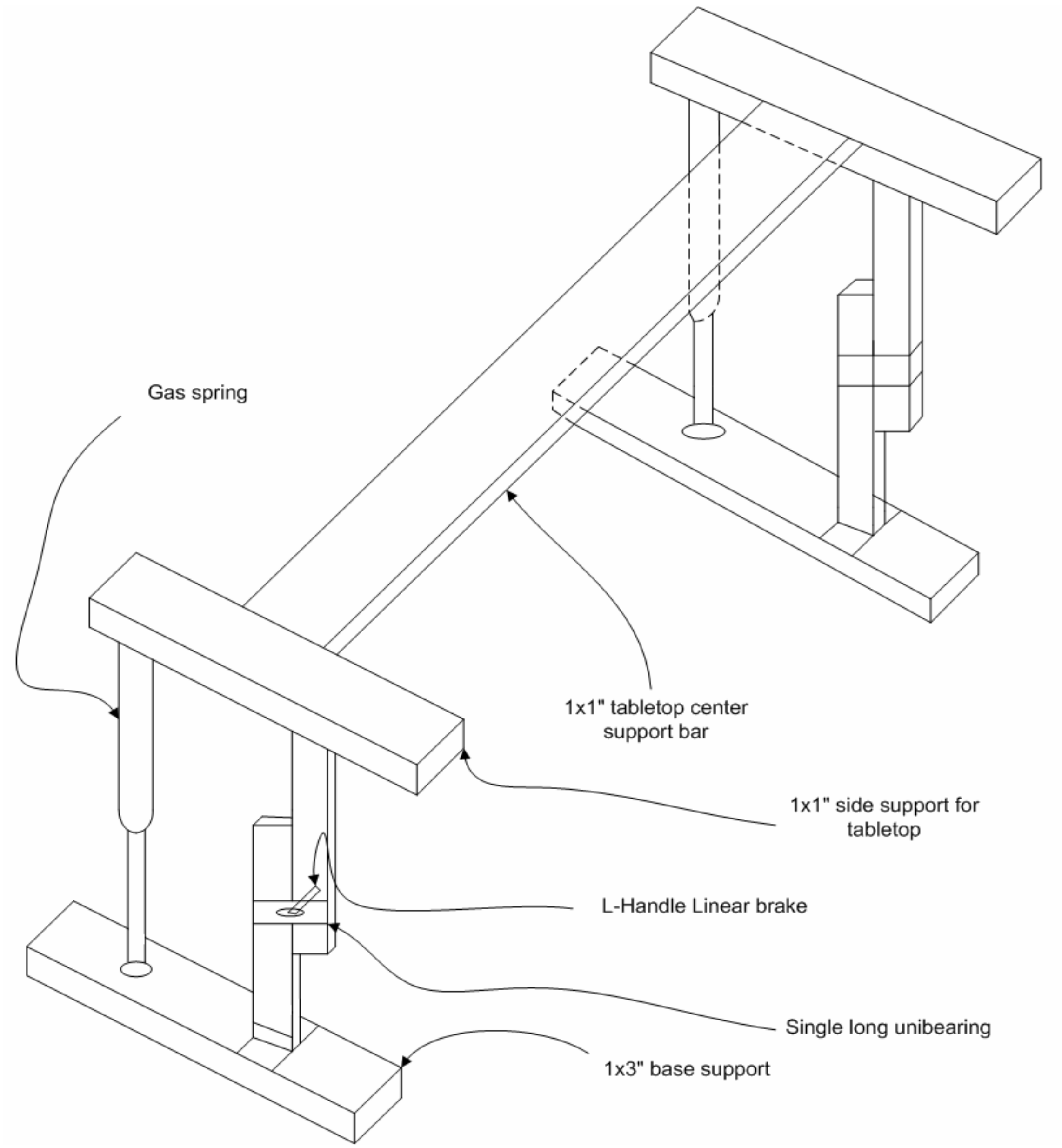

Figure 31: Complete frame design of table

2.2.2.3. Upper Framing

The upper framing of the table is designed to completely attach underneath the tabletop. This will secure that the tabletop will remain in place at all times. A schematic of the upper framing can be seen in Fig 32. on the following page. The sides underneath the tabletop will be fully supported by the 1010 extrusion. Another piece of 1010 extrusion will run straight down the middle connecting the two sides. This setup will be bolted flush underneath the tabletop. This will allow the maximum leg room possible for the user while still remaining strong and stable at the same time.

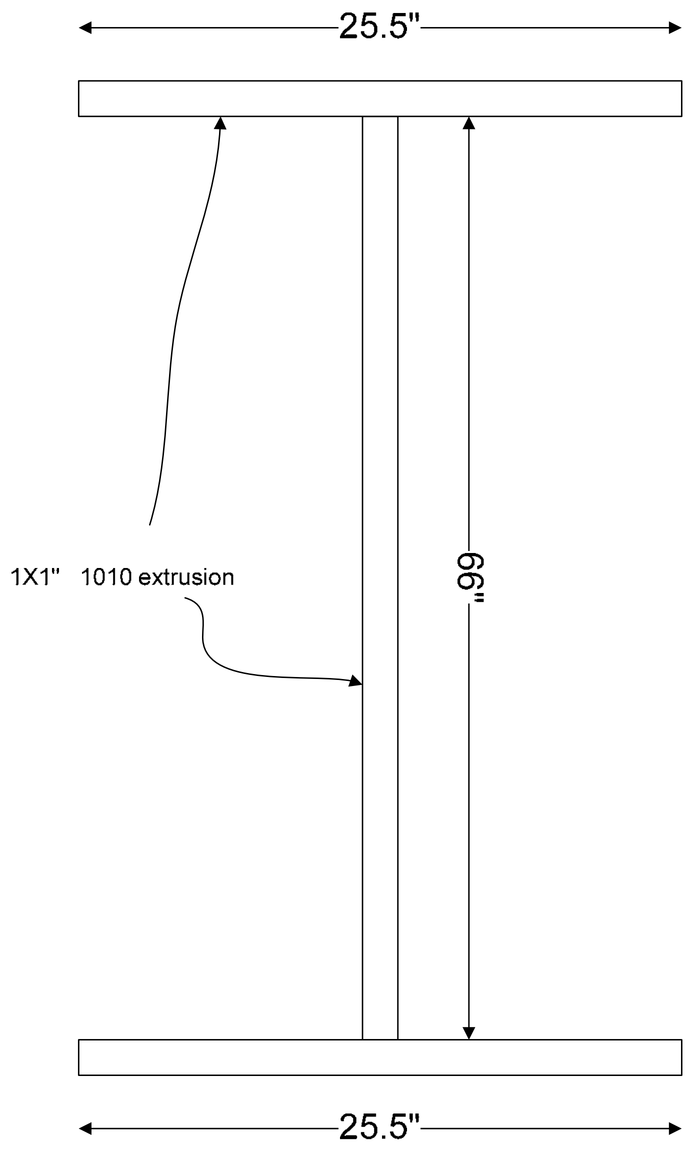

Figure 32: Dimensions and orientation of upper framing

In order to successfully attach the tabletop to the upper framing, 90 degree corner brackets were required. These brackets would be bolted in between the 1010 extrusion and the tabletop itself. Bolting the upper framing to the tabletop required many corner brackets to make the connection fully secure. Instead of purchasing more of these brackets, they were going to be manufactured in the machine shop instead. A schematic of one of these corner brackets can be seen in Fig. 33. These brackets were going to be a bit smaller in thickness when compared to the original corner brackets from 80/20. This required the purchasing of 3/8” screws. The original ½” screws would be too large to be fully tightened into the corner brackets along the 1010 extrusion.

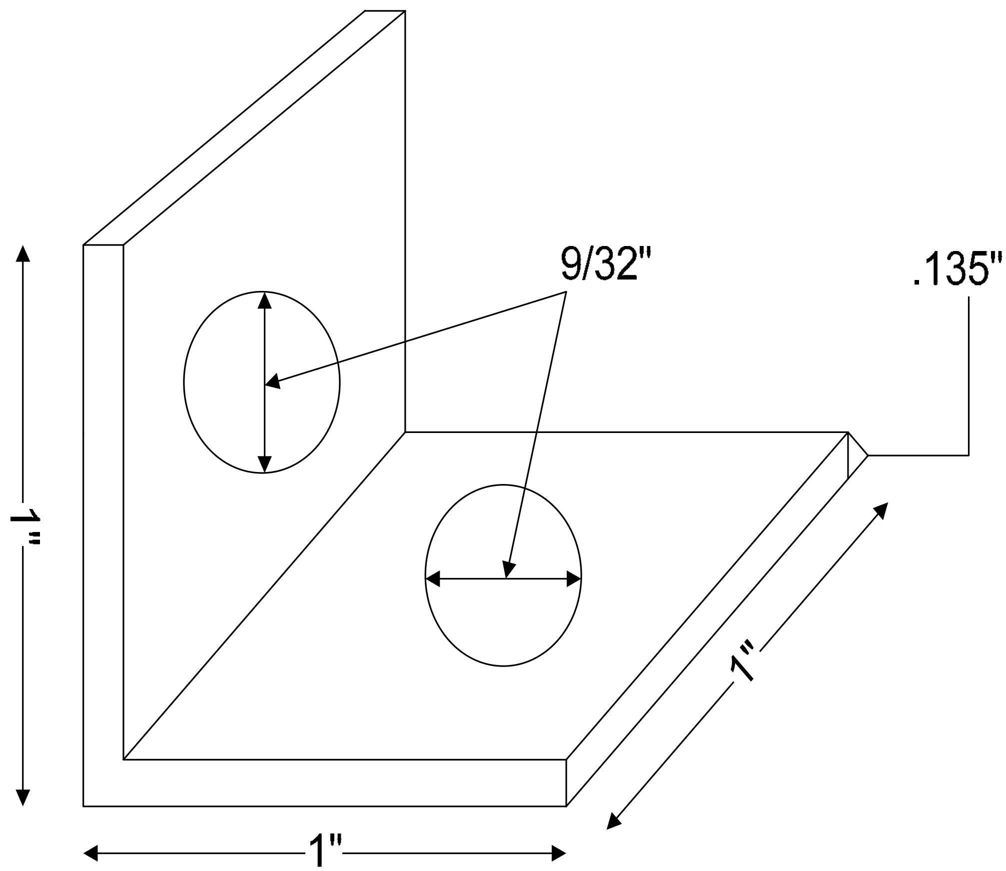

Figure 33: Dimensions of new manufactured corner brackets

Once all of the new brackets were manufactured, the tabletop would be attached to the upper framing. This had to be done very carefully. Holes had to be drilled into the tabletop in the precise areas where the brackets were going to be placed. Large threaded screws were going to be used to screw into the tabletop. These screws were chosen due to the fact that the tabletop was made of a plastic resin composite. This composite is very flexible, and would quickly tighten around the screw as soon as it was screwed in. Once a screw was put into place, it could not be removed. If a screw were removed from its original location inside the tabletop, it would not be nearly as tight if it were screwed in the same place again. Fig. 34 shows a diagram of where the brackets would be placed in relation to the upper framing underneath the tabletop

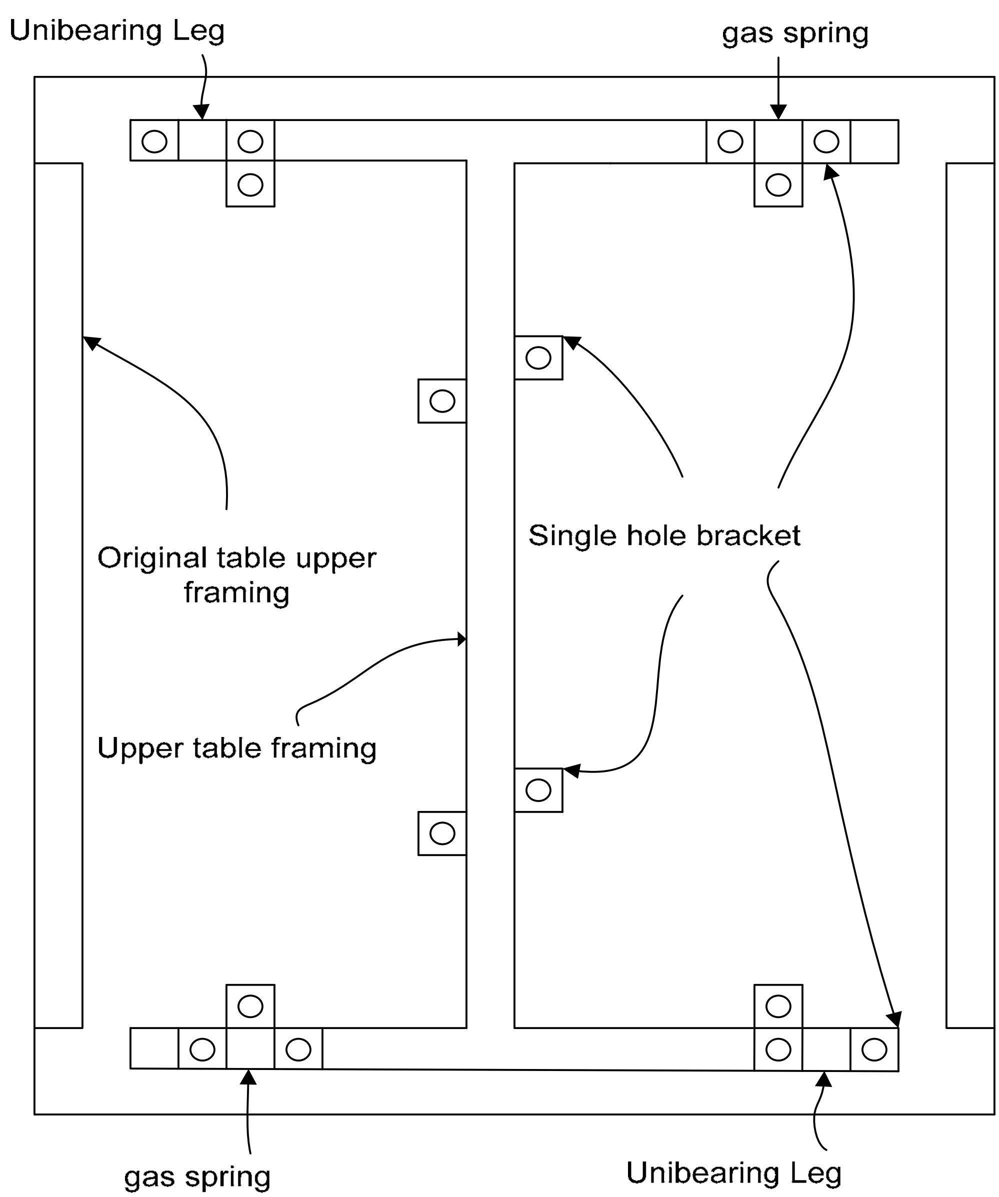

Figure 34: Orientation of corner brackets and upper framing underneath tabletop

2.2.2.4. Support Legs

The sliding unibearing legs are another important component of the framing setup. These legs are going to be fabricated out of 1X1" 1010 extrusion. Each leg will consist of two smaller legs which will slide together in parallel via a single side long unibearing which will be discussed in greater detail in the sections to come. The lower sliding leg will be bolted down to the base, while the higher leg will be bolted to the upper framing. A schematic of this can be seen in Fig. 35.

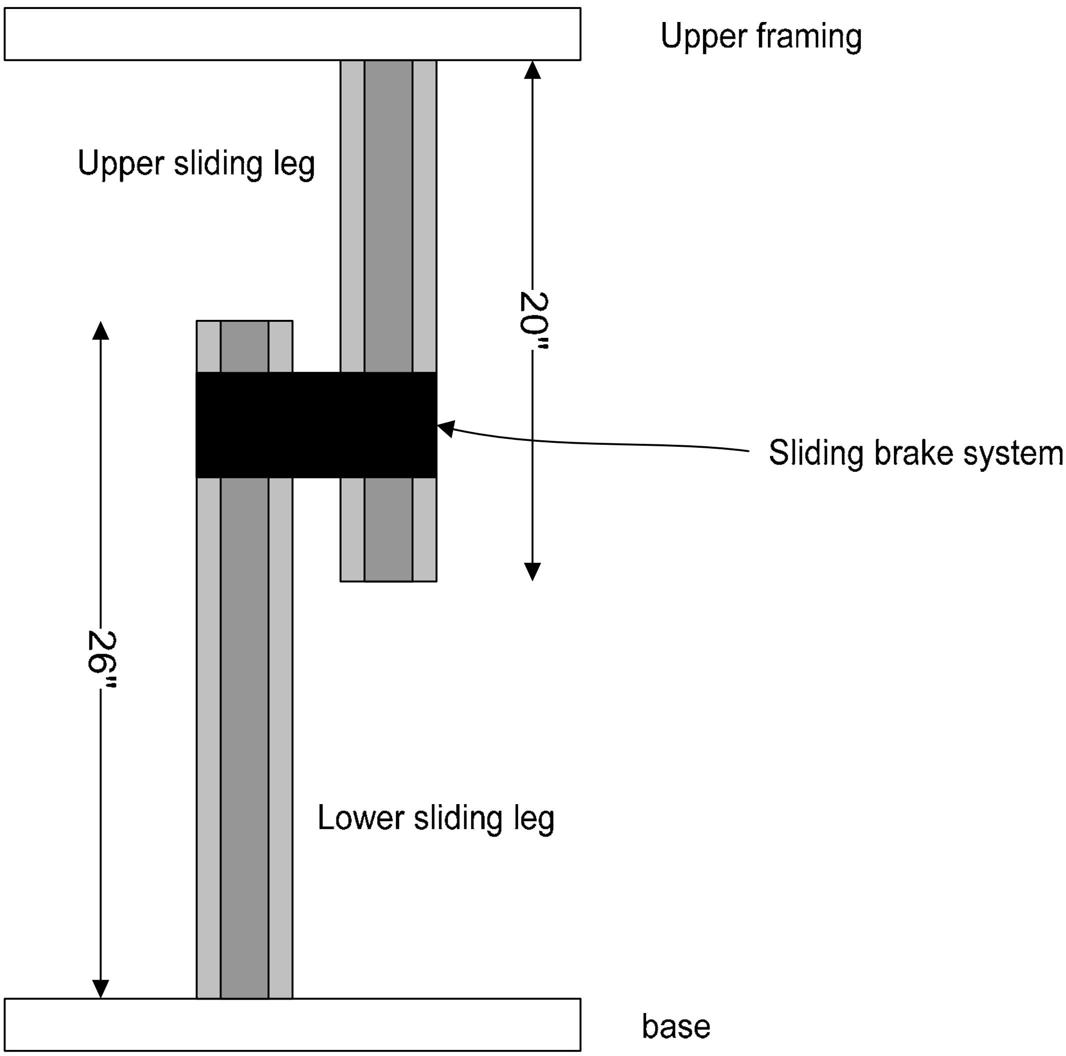

Figure 35: Dimensions and orientation of sliding unibearing leg

The connection between the upper unibearing leg and upper framing had to be extremely secure in all directions. If it was not secure in all directions, it could cause the whole table to be off balance and lose its stability. The whole table was briefly put together and tested for stability. It turned out that the framing was extremely wobbly and unstable due to the connection between the upper framing and unibearing leg. In order to fix this problem, a much stronger bracket was needed which would provide enough reinforcement to the connection so that it would not pivot about its axis. The solution for this problem can be seen in Fig. 36.

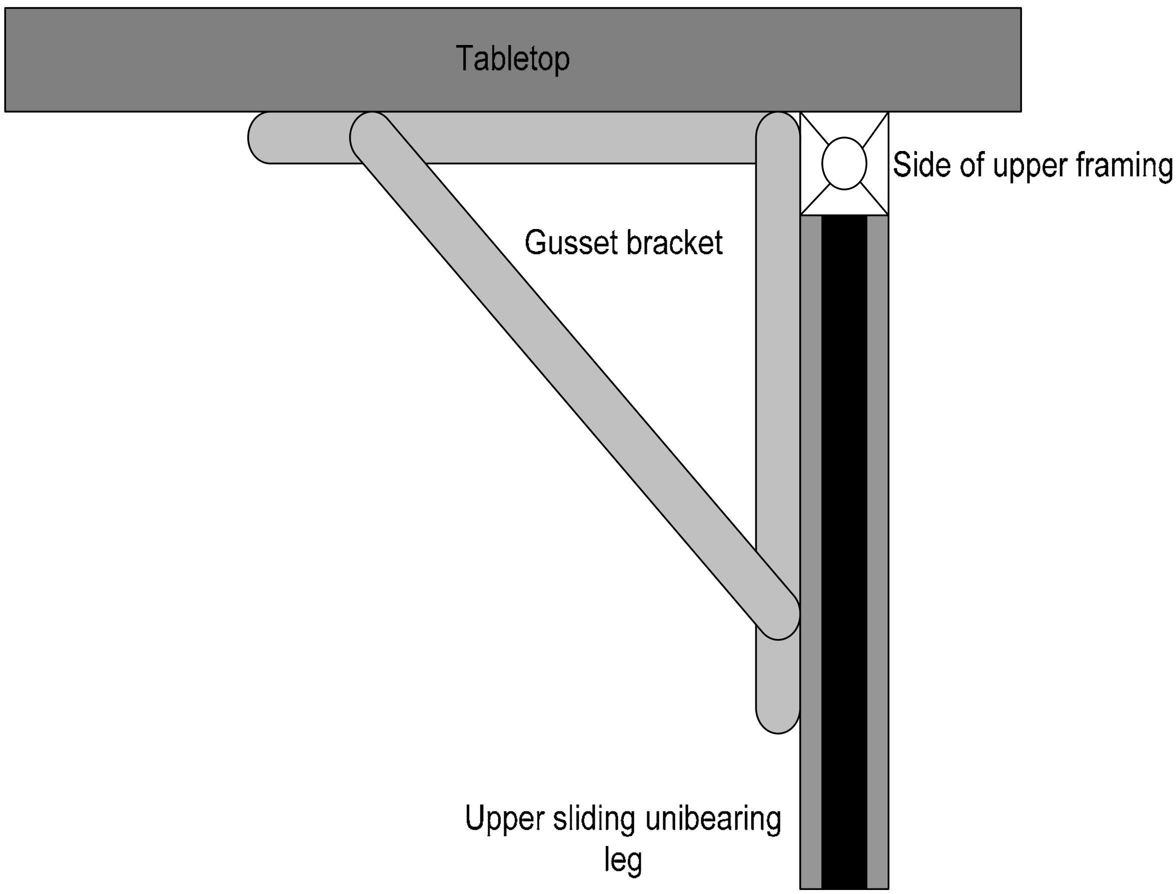

Figure 36: Gusset bracket reinforcing upper framing and leg connection

It is easily seen that the gusset bracket is bolted flush against the sliding leg, upper framing, and the tabletop. A second gusset bracket identical to the one above will be placed in the same orientation for the connection between the upper framing and the unibearing leg on the opposite side of the table. This extra reinforcing bracket will take away any swaying that would occur around the connection between the upper framing and sliding unibearing leg. This was the case upon further testing of the table when it was constructed for the second time.

2.2.2.5. Unibearings

The unibearing is the mechanism which allows a part of the table to adjust in height. A unibearing consists of two extrusions which run parallel and adjacent to each other with a unit, known as the unibearing itself, and two brakes. All of the parts work in conjunction to allow the extrusion to move when it is desired to move, and to stay put when the brakes are locked. The unibearing works using friction; the extrusion is held so tightly that it does not move. When the brakes are loosened, the extrusion is free to slide along a plastic piece which provides a smooth surface for gliding. Therefore the amount that the unibearing can hold depends on how tightly the user makes the brake. Although this relies on the user significantly, there is no way to have this system automatic.

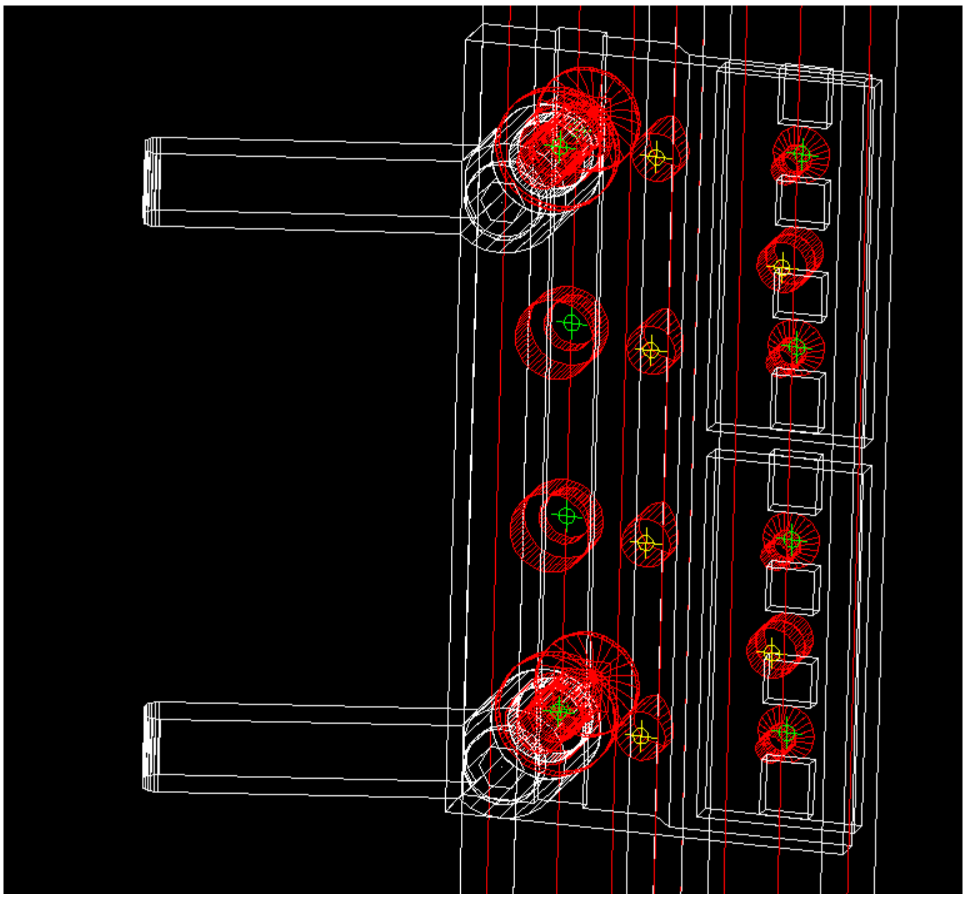

Figure 37: AutoCAD design of the Unibearing and Brakes Connecting to the 1010 Extrusions

This AutoCAD drawing shows how the unibearing looks through the extrusion. The two handles are two the left and it is these that essentially hold the extrusion to the unibearing when the handles are tightened. The plastic sliders that were mentioned previously are on the right and consist of the two sets of four rectangular shapes. The drawing depicts how the two extrusions run parallel to each other, vertically, and the unibearing connects the two together. In general, this whole apparatus serves as two of the four legs on the table.

So for these unibearings to be of any use, it is necessary that one of the extrusions connects to the frame of the tabletop above and with the base on the bottom. The extrusions are connected in the regular fashion with inside corner brackets, on both the top and the bottom. Exactly how the unibearings fit in between the two extrusions is depicted in the following figure, below:

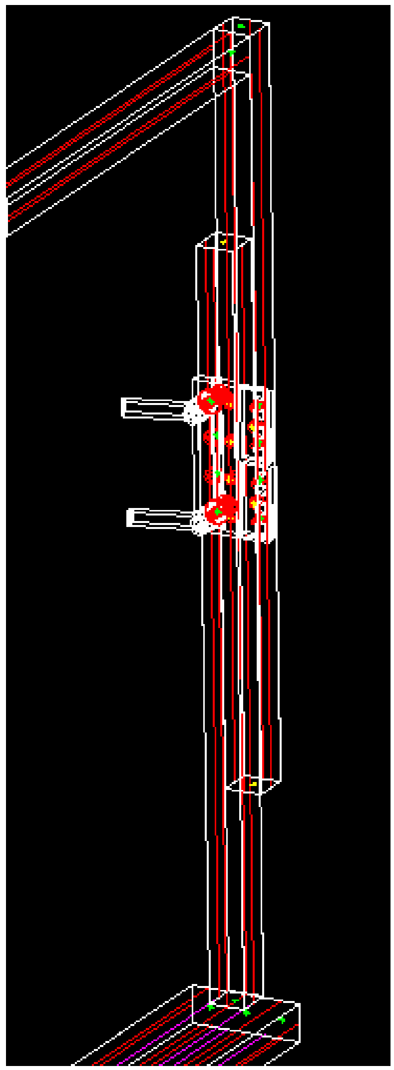

Figure 38: View of Gas Spring Representation and Linear Motion Mechanism

Assembling the unibearing unit required minimal installation. There were only screws that used an Allen wrench. The rest of the unibearing was installed so that it slides into the tracks of the extrusions. The brakes are put onto the unibearing by turning them on screws that come out of the unibearing. These could be particular because if the brake itself is disassembled into its parts, such as the plastic handle and the inner nut then the brake will not function properly. Instead one would have to push in on the brake handle in order to loosen it. This is clearly not what the user desires, so the inner nut will have to be taken out and put into the handle properly.

One of the L-handle brakes was defective because the spring was assembled on the wrong side, so that had to be fixed before the remainder of the table could be put together. A picture of one of the unibearing devices, as it appears completed, is below.

Figure 39: Unibearing Setup with L-Handle Brakes

A problem that was encountered with the unibearing was that when the L-handle brakes are fully disengaged, then one 1010 extrusion can slide all the way through the bearing. This could be a problem when the user tries to raise the table too high. If this is the case, additional pressure could be put on the mounts of the gas springs, or the gas springs themselves. Therefore the team devised a stopper that could be used in order to prevent the extrusion from traveling completely through the unibearing. A drawing of the stopper appears in the figure below.

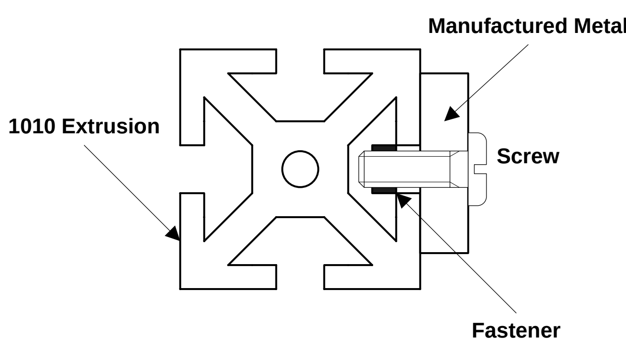

Figure 40: Stopper for Vertical 1010 Extrusion

The stopper consists of a screw, a fastener, and a manufactured piece of scrap metal. The metal is there to give the screw enough tension on the fastener that is inside the 1010 extrusion, as denoted by the black piece around the screw in the above figure. With this stopper, the table will not be adjusted to heights out of the desired range. Of course, a stopper is not necessary for the top of the extrusion because this range of motion is physically impossible with the presence of the tabletop.

The stoppers were manufactured and are show in the following photograph. This would keep the extrusion from coming off of the track. These mounts were simply pieces of metal with a hole drilled in them. The stock metal used was the same metal used for the brackets. This meant that both the stoppers and the brackets were 1/8” thick, which required a different size 80/20 screw than we already had. These screws also fit the corner brackets that were previously machined. There are two stoppers needed—one for each unibearing, which is why two appear in the figure below. The unibearings appeared to be complete, pending further testing.

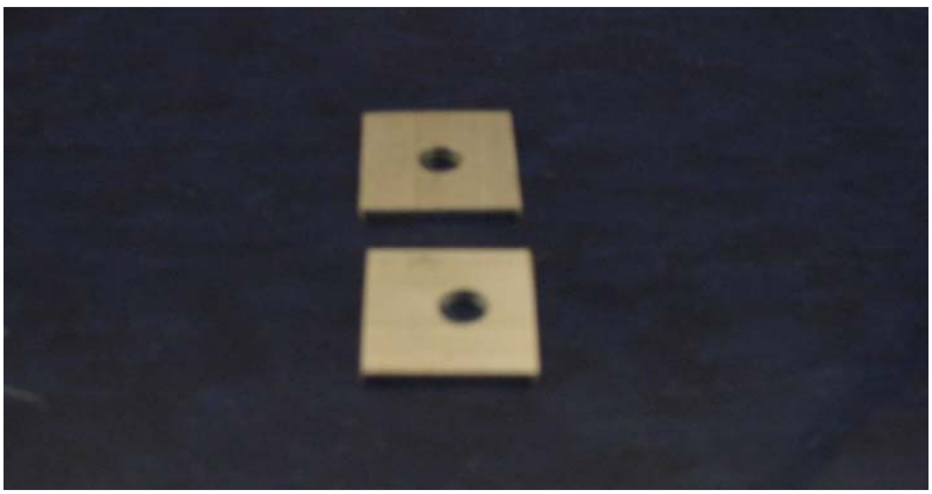

Figure 41: Mounts for Unibearing Stoppers

Unibearing Testing

The unibearings were first tested for functionality before they were installed on the table. We decided it would be appropriate to subject the unibearing to as much weight as possible to see how much they could hold when fully tightened. The unibearings were attached to the base of the table so that there was more to hold on to during testing. The testing took place at the Student Recreational Facility. Weights were placed on the top of the unibearing and were stabilized. This process was continued repeatedly until all of the desired weight was added to the unibearing. A total of six 45 pound weights were applied before it was decided that it could be unsafe for them if any more weights were added to the leg. When all of the weights were on, we also applied a bit more force from his own body weight which caused the scale to climb to over 300 pounds. Pictures of this setup as well as the scale reading can be seen in the following figures.

Figure 42: Testing Setup

Figure 43: Largest scale reading when max force applied

The unibearings were then put in the proper place, one on each side of the table, diagonally from each other. The following figure shows the table as seen from above, where the gas springs are diagonal, and the unibearings are also diagonal.

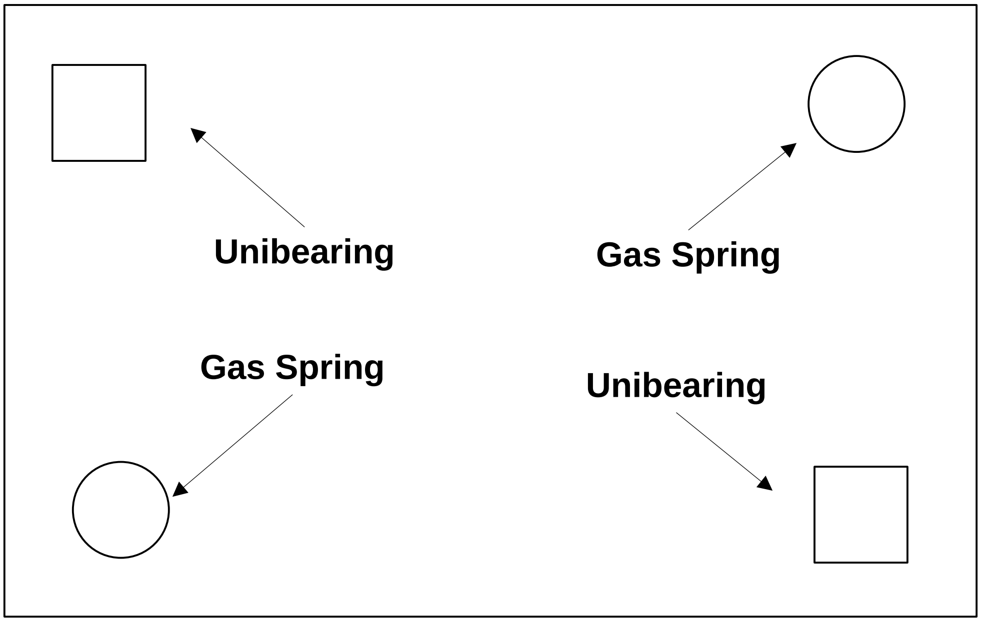

Figure 44: Setup of Leg Types

The unibearings were put on diagonals in order for the table to raise without twisting. When the table is being raised, the gas springs push up on the bottom of the table. Since the gas springs are on diagonal corners, the table will raise level. The unibearings worked fine without any of the rest of the table interfering, but when the unibearings were installed on the table, many more problems were encountered.

Problems Encountered After Installation

The unibearings that were originally intended to smoothen the height adjustment process actually caused most of the problems. The team discovered that the table does not adjust smoothly because of the linear motion bearings. The legs do not adjust smoothly unless they are kept in the correct alignment. When the gas springs raise the table, the tabletop twists because the gas spring is pushing up so far away from the unibearings. This can be seen in the following diagram:

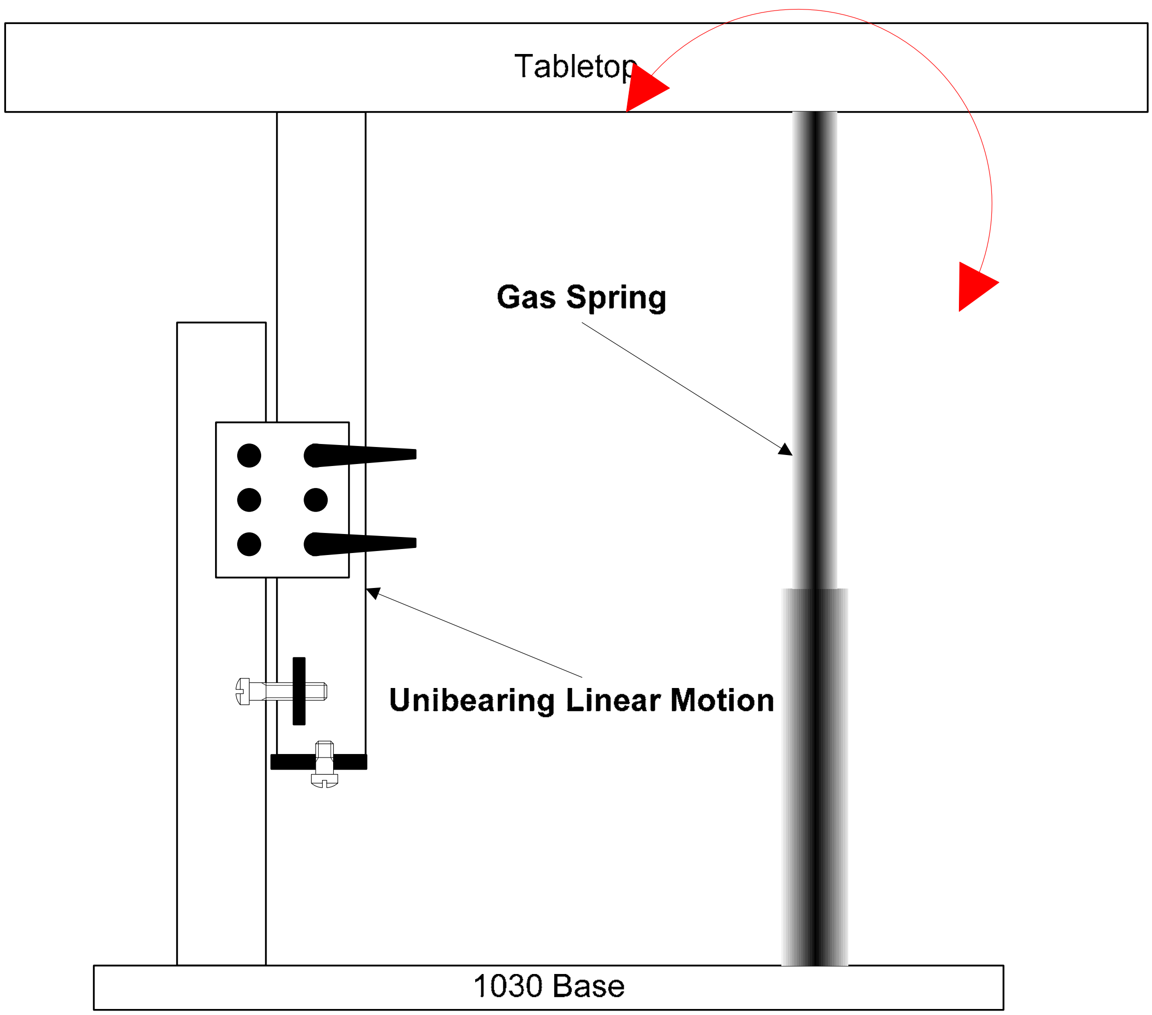

Figure 45: Torque encountered when raising the table.

As a result of the torque in the previous diagram, the extrusions that are connected by the unibearing want to twist out of place. The bottom of the upper extrusion rubs extrusion that connects to the base, so the adjustment is no longer smooth. An unacceptable amount of friction is put on the two extrusions, as diagramed below.

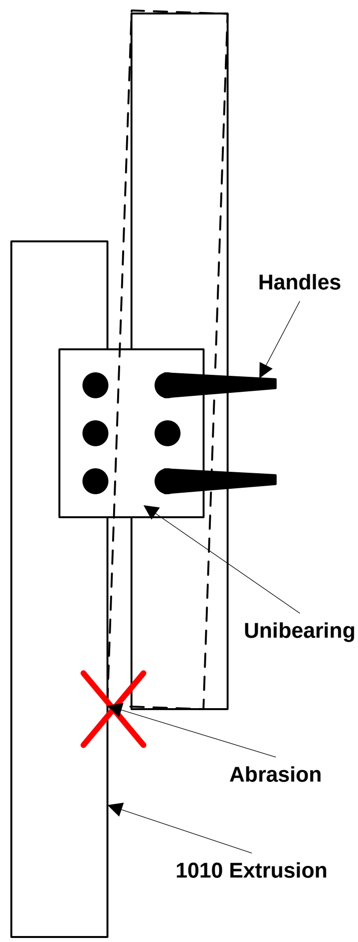

Figure 46: Diagram of Linear Motion Problem

The misalignment occurs because the bottom of the extrusion used for the top leg hits the bottom fixed leg. We determined that the best way to fix this would be add a cushion between the two legs to keep them from touching. The group picked up some rubber which could be used as a buffer between the two extrusions. The team decided that something that could be securely fastened and that would be virtually frictionless would be ideal. At first we thought that a rubber piece would be best in order to keep the legs totally in track, so we tested this route. A picture of the stock rubber, this setup and a diagram of the problem can be seen below.

Figure 47: Stock Rubber 1/16” Thick

The stock rubber was cut into strips, and then tripled in thickness. The unibearings were then retested with this rubber in place, as seen below.

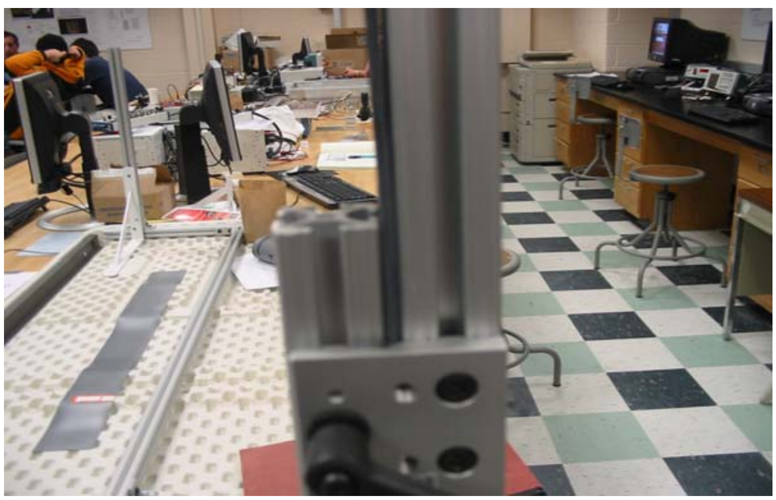

Figure 48: Rubber in Place on Extrusion

The rubber had a thickness of 1/16” and the space between the two legs was approximately 3/16”. By super gluing three strips of the rubber together we were able to make a cushioning strip that was the exact thickness needed to keep the extrusion in line. We attached the rubber cushion temporarily to one of the legs and discovered that under non-load bearing situations this worked well, without the tabletop attached. However when the tabletop was attached, the rubber proved to make too much friction when the table was adjusted. The amount of friction that it was making was actually preventing the tabletop from raising. The group thought of another idea, which no longer included the rubber.

First, since the unibearing was able to slide along the wide base (1030 extrusion), it was slid closer to the gas spring. This meant loosening, with the Allen wrench, the screws that hold the four hole and two hole corner brackets to the extrusions onto the base. The location of the unibearing actually made a significant difference in the performance. The closer the unibearing was to the gas spring, the less torque there was, so the easier it was to raise the table.

Second, the team developed a screw and t-nut apparatus that would hold the two extrusions apart at a constant distance. The rubber helped the extrusions from rubbing together, but it did not prevent the extrusions from pulling apart. The screw and t-nut setup helped to prevent the two extrusions from pulling apart. A figure of the setup can be seen below.

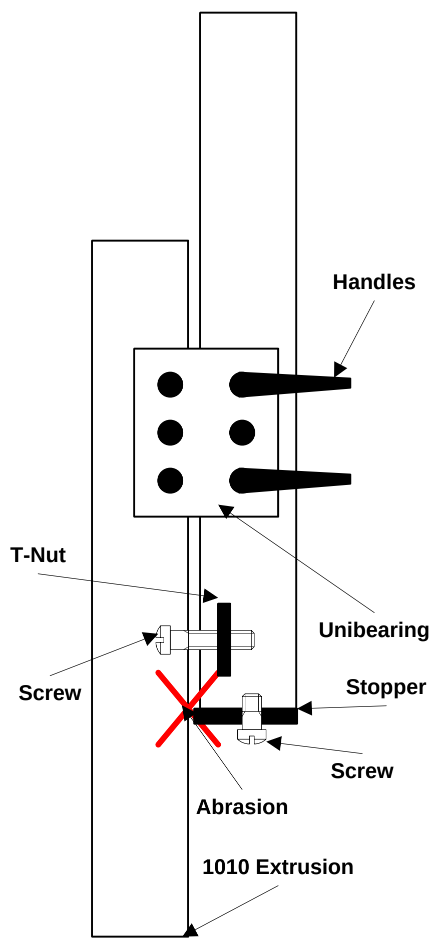

Figure 49: Alternative design to prevent excessive friction on the extrusions

The setup was implemented on the extrusions. This required putting the head of the screw down the track of one extrusion, and then the t-nut down the track of the other extrusion and connecting the two together. A photograph of this setup appears in the figure below.

Figure 50: Second idea to prevent excessive friction between the two extrusions

This idea worked decently, but not enough for the tabletop to raise to the full 42 inches. Another idea was developed so that there was less give between the two extrusions. It was implemented by drilling a hole through the extrusion and putting a long screw through it. The screw was then connected to the other extrusion through a t-nut and screw from a local hardware store.

It became difficult to continually tweak the unibearing because of this screw. This screw that was preventing the two extrusions from becoming out of line was also connecting the two together so that they can not be adjusted easily. In order for the unibearing to be moved, or for the extrusion to be taken off the tabletop, the screw had to be taken out of the extrusion, which was a significant task considering it screwed into a regular nut and a t-nut. Since the table was standing up, the t-nut tends to fall to the bottom of the extrusion. Additionally the nut was becoming abrasive with the extrusion upon lowering the table. The metal was gouging into the extrusion, and shavings of metal were coming off upon lowering the table. The team experimented with using automobile grease in order to lower the amount of friction, but this proved to be only temporarily successful. A photogram of the screw that connects the two extrusion appears in the figure below.

Figure 51: Screw Connecting the Two Extrusions on Unibearing

An alternative design that was the most successful involved using the break on the side of the extrusion. This provided the ideal separation between the two extrusions. The extrusions could not be too close or they would cause too much friction. They could not be too far apart either or else they would kink on the unibearing and prevent them from gliding smoothly.

We decided it would be best to take out the screw in one of the sliding legs and attaching a corner bracket underneath the upper sliding leg. This setup can be seen in the figure below. This bracket served as a stopper and also aided in the movement of the two extrusions.

Figure 52: Bracket below the upper sliding leg

For the other unibearing leg, the screw was left in place, but the nut which was in between the two sliding legs was taken out. This nut was causing a great amount of friction when the table was being raised up. In order to keep the screw in place, a single square bracket was put on the outside of the upper extrusion which ended up covering almost half of the screw head. The other end of the screw was screwed flush with a t-nut inside the lower sliding leg. This setup can be seen in the figure below. This setup enabled the two sliding legs to constantly stay apart during the whole lifting process without a nut in between them.

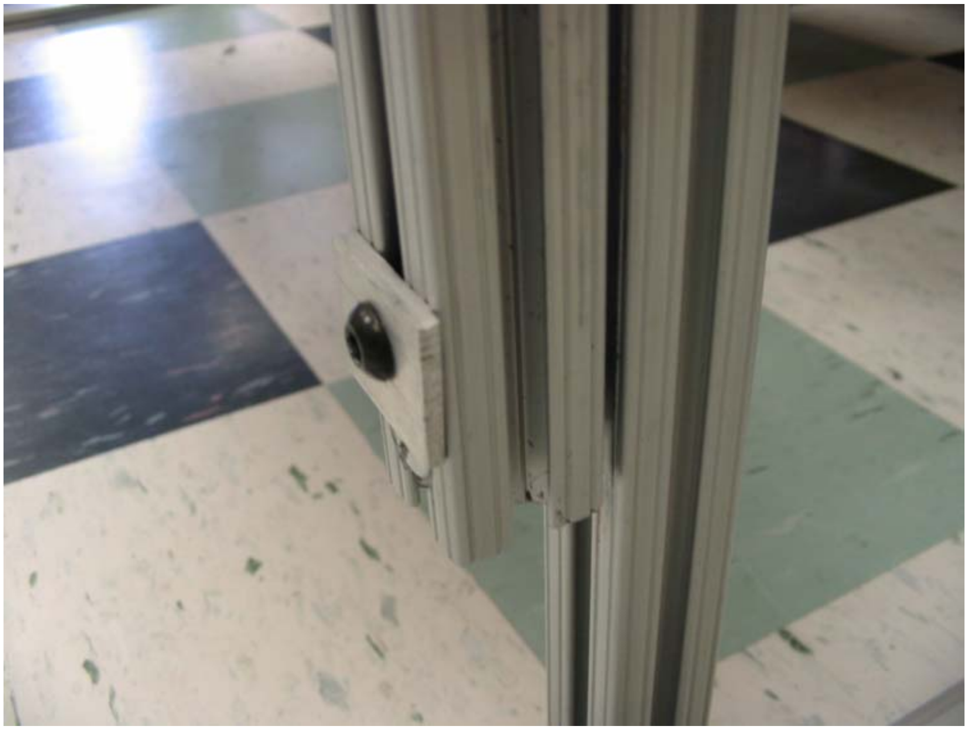

Figure 53: Bracket below the another upper sliding leg

Proper Use

The breaks on both legs must be disengaged before any height adjustments are made; this is to allow for proper adjustments and to maintain the integrity of the table. It is also essential to have the brakes locked during use to ensure the safety of the user and the stability of the table. When locked, the brakes have the ability to hold at least 300 lbs per leg. This locking power ensures that no accidental adjustments can occur to the extent that harm could be inflicted on the user. To ensure that the brakes are completely released before adjusting, turn each brake handle counter-clockwise one or two turns until the brake feels loose. To lock, turn each handle clockwise until rotation can no longer occur. It is necessary to get a feel for how much the handles can be turned, because sometimes they can be tightened to the point where it is extremely difficult to loosen. A schematic of how the unibearing is tightened and loosened appears in the figure below.

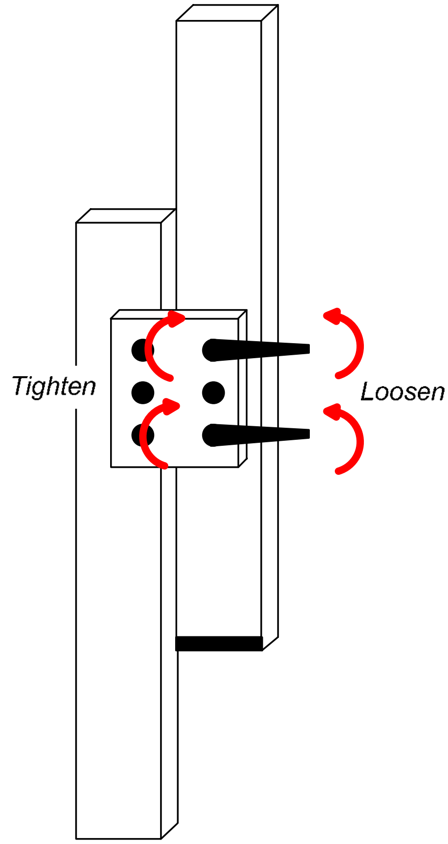

Figure 54: Brake System Operation on a Diagram

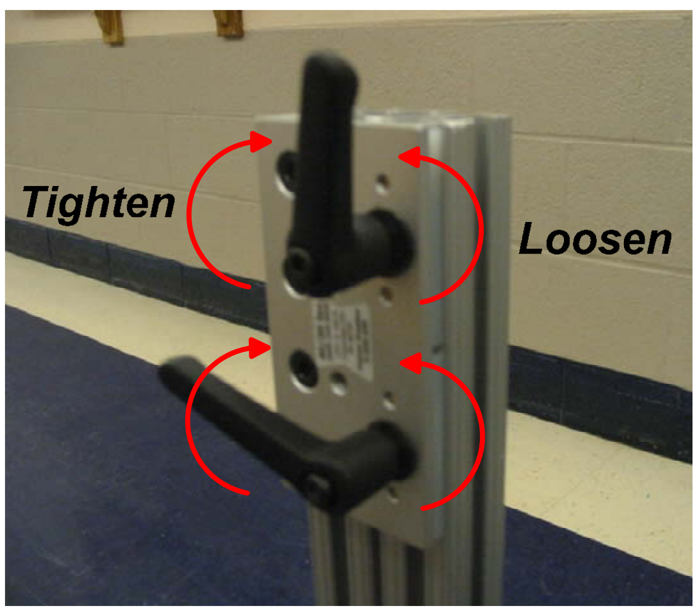

Figure 55: Brake System Operation on the Unibearing

These figures show that both handles must be tightened. Although only one tightened handle will prevent the table from raising, only one is not sufficient to prevent the unibearing from moving. The handles should be tightened enough so that they hold the extrusions in place, but not too tight so that the handles break or they cannot be loosened. Sometimes the handles actually hit each other, such as when the top handle is pointing down, and the bottom handle is pointing up. Therefore, one handle should be tightened at a time so that it is out of the way of the other handle. This schematic is shown in the following figure.

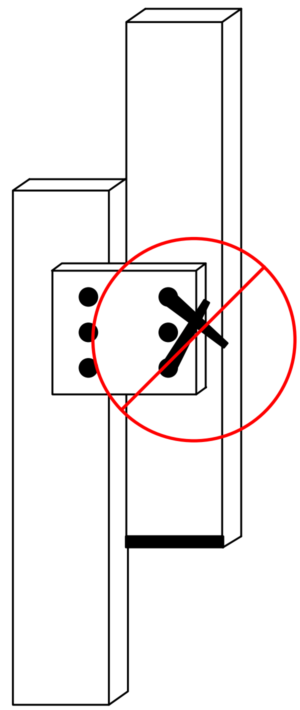

Figure 56: Try to avoid having the two handles interfere

If the two handles interfere with one another, then it will be difficult to tighten them to their full potential. Instead, one should take an approach where one handle is tightened so that it is in a position out of the way. Then the second handle should be tightened so that it can rotate freely.

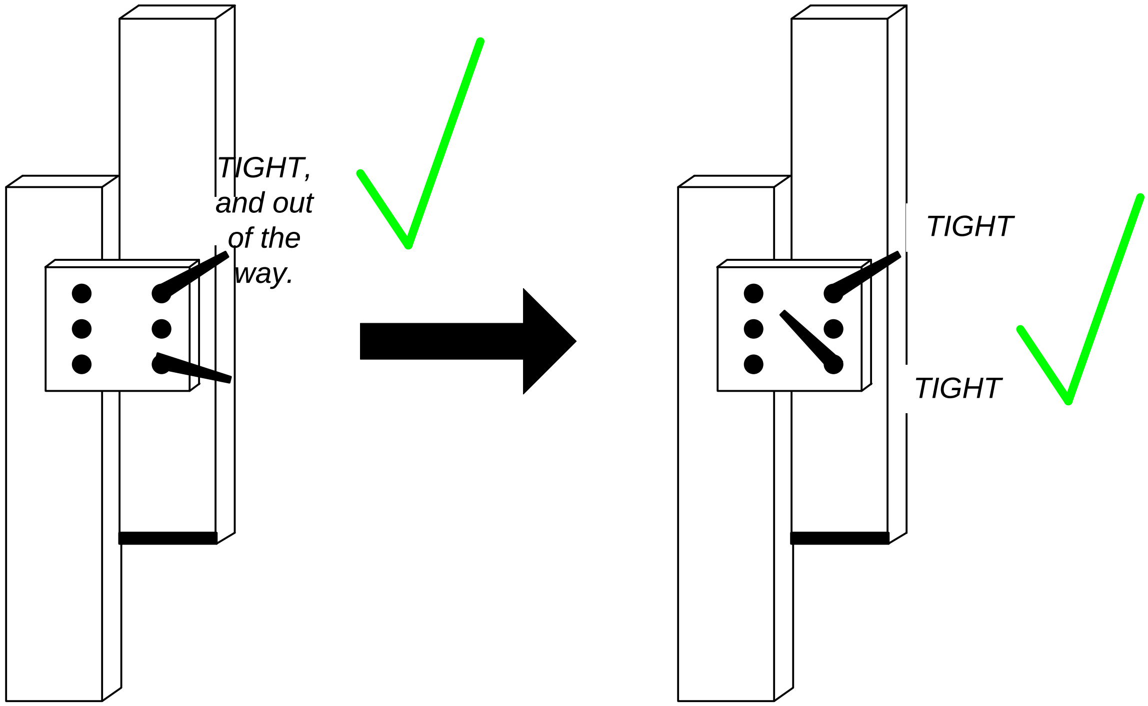

Figure 57: Instead, tighten one so that it is out of the way, then tighten the other

In the previous figure, the upper handle was tightened by turning it in the clockwise direction. This handle was tightened to a point that it was out of the swinging space of the lower handle. The lower handle can now be tightened with no problems.

2.2.2.6. Gas Springs

Gas springs utilize pressurized gas to supply the necessary force to extend a piston. The gas springs used in this table consist of a 22 mm diameter cylinder filled with nitrogen gas that applies constant force on a 10 mm diameter piston rod. The gas is filled in the cylinder so that it applies 14 pounds of force on the base of the piston rod. The base of the piston rod is slightly smaller than the 22 mm diameter cylinder, close enough so that no gas can escape but also small enough so that the piston can slide up and down unobstructed. When the forces applied onto the gas spring, such as the weight of the tabletop or external forces applied by a user, exceed the force applied by the pressurize gas the piston will be forced into the cylinder and the table will lower. When the forces are less than the force of the pressurized gas the piston extends out of the cylinder and the table rises. The piston is long enough so that it can move a distance of 13 inches out of the cylinder. This distance is the stroke length, which corresponds to the amount of adjustment that is possible. A diagram of this can be seen below.

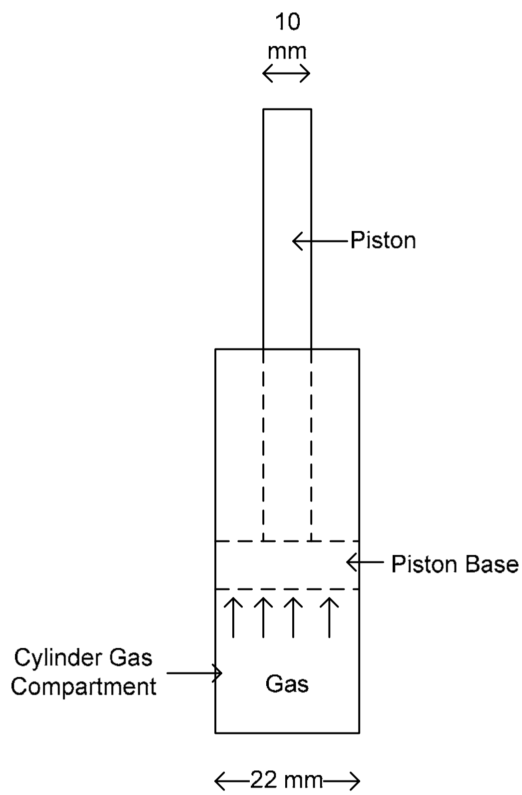

Figure 58: Gas Spring Setup

The force applied by the compressed gas is directly related to the pressure the gas is kept at. The force applied by an amount of gas can be related to the pressure based on the area of the surface the gas is pressing against.

$$Force = area \times pressure$$

Our gas springs were specified to produce 14 pounds of force, so the nitrogen gas has to be kept at a pressure of 20.6 pounds per square inch (psi) to produce the 14 pounds of force. The weight of the tabletop and framing is approximately 25 pounds, so there is enough force from the two gas springs combined to raise the table, and there is also not too much force to make lowering the table extremely difficult. As the piston is pushed further out of the cylinder, the volume of the gas increases and the pressure decreases slightly. This causes the force produced by the gas spring to decrease slightly at the end of the piston stroke. So, when raising the table it is sometimes necessary to aid the gas springs over the final inches. The small decrease in pressure can make the force generated less than the force necessary to overcome gravity, friction, and the weight of the table. Therefore, in these situations the tabletop will not rise under its own accord. Very little force is required from the user in these occasions, just enough to help overcome these external forces.

The most important feature of these gas springs is the locking feature. Most gas springs are not locking springs, so they are continually forcing the piston out of the cylinder unless the external forces are greater than the force produced by the compressed gas. These gas springs are often used in applications such as lifting aides in heavy doors or lids. The gas spring only stops in the fully extended position, which would not be suitable for an adjustable table that needs to be able to stop at any height between its maximum and minimum. The locking gas spring utilizes a release lever in the cylinder that only allows motion when it is disengaged. There are two types of locking gas springs, rigid blocking and elastic blocking gas springs. Elastic blocking springs are filled only with nitrogen gas, and when locked will give a bit when external forces are applied. This creates a bounce effect on the spring such as in computer chairs, where a person is cushioned as they sit down. The rigid blocking springs resist all movement once locked, which is achieved by including a compartment of oil in the cylinder in addition to the nitrogen gas. The oil is not as easily compressed as the nitrogen gas, so when the external forces are applied the spring remains securely in place.

The specific gas springs used in this table are the rigid blocking in the push in direction from Easylift of America. These gas springs utilize a "floating piston" in between the gas and the oil layers. The piston presses on to the oil when the gas spring is locked and under compression. In the elastic blocking gas springs, the piston presses onto the nitrogen gas. Nitrogen gas is easier to compress than the oil, this is why the bouncing effect occurs when forces are applied to the elastic blocking springs.

The locking force of the table is very strong when in the locked position. The springs are specified to be able to hold approximately 2500 pounds without slipping. This is much more than can ever be expected to be loaded onto the table. The largest load on the table that can be expected to be experienced is the weight of a person sitting on the table.

The positioning of the gas springs is very important when examining the stability and functionality of the table. There are three ways to configure the placement of the legs. The first way would be having both of them on the same end of the table as seen if Fig. 59. The second way would have the two legs on opposite ends of the table, but on the same side as in Fig. 60. The final setup, the configuration that we decided is the optimal setup, would have the two legs on opposite sides and opposite ends to perfectly balance their adjustment. This is depicted in Fig. 61.

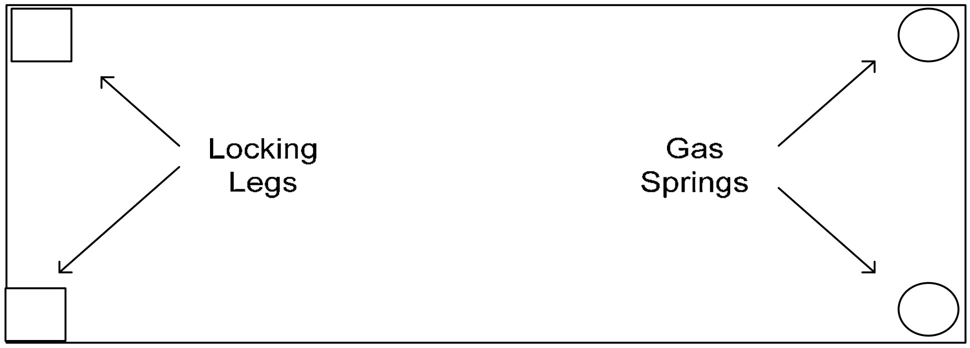

Figure 59: Setup 1

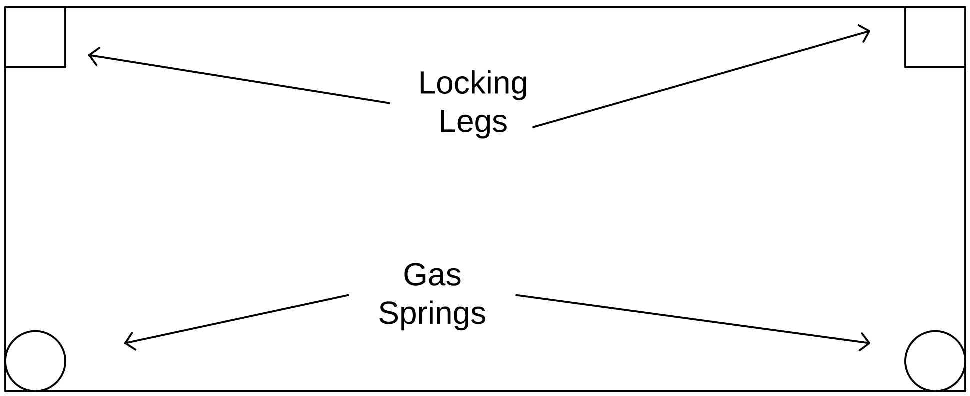

Figure 60: Setup 2

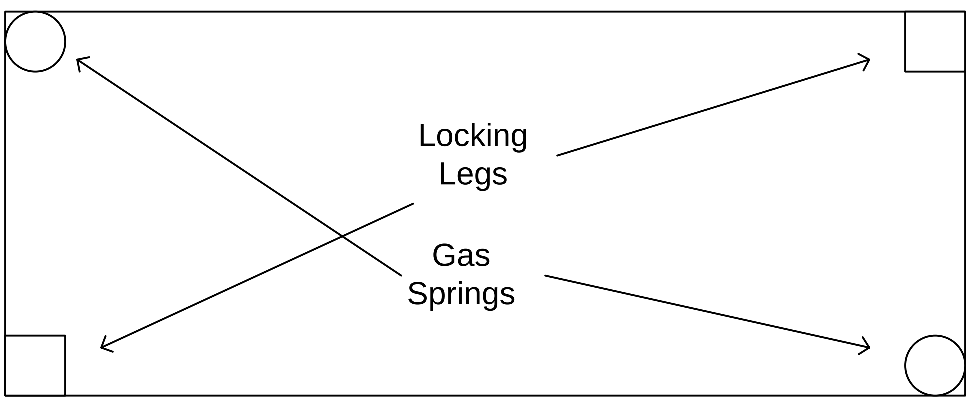

Figure 61: Setup 3

Figures 59 - 61 can be used to analyze the torque and forces required from the gas springs in the three configurations. For the first configuration the following equations show that there are considerable moments around the two gas springs created by the weight of the tabletop.

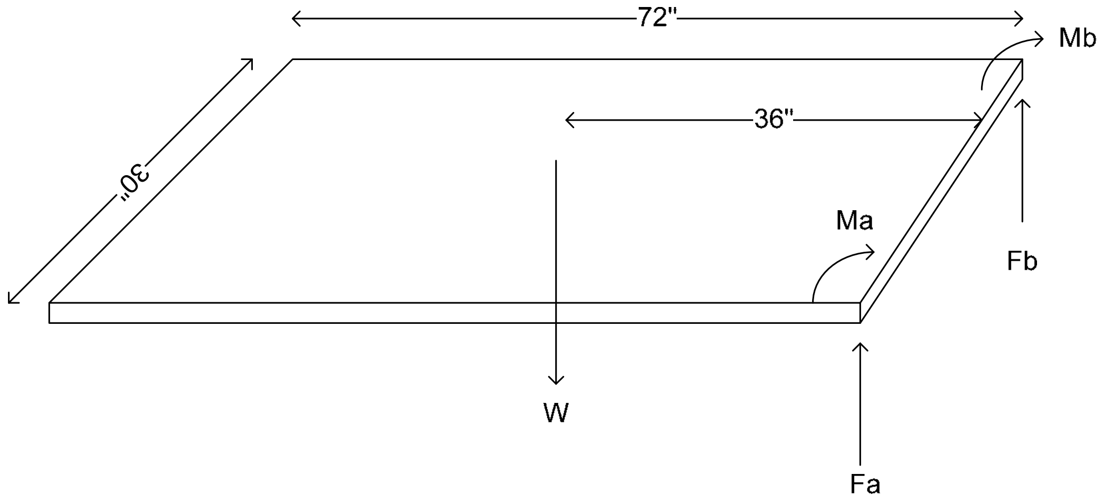

Figure 62: Free Body Diagram of Setup 1

$$\sum M_{AB} = 0 = 36W - M_A - M_B$$
$$M_A = M_B$$
$$M_A = M_B = 18W$$

The moment created by the weight of the table being centered so far away from the lifting legs is very large. This would put a lot of stress on the joint between the gas spring and the tabletop. This also would make it very difficult, if not impossible, to raise the table using just one person. This setup would require a second person on the opposite end using considerable force to lift up the table. This estimate is also probably lower than the actual moment created at each mount. The weight of the table is assumed to be centered on the tabletop. In reality there is weight distribution all over the table, so there is some weight at the far end causing a very large moment.

For the second configuration the weight of the table would again cause torque around the gas springs, but because the width of the table is much less than the length this would not cause as many problems as the first configuration. The following equations show this torque.

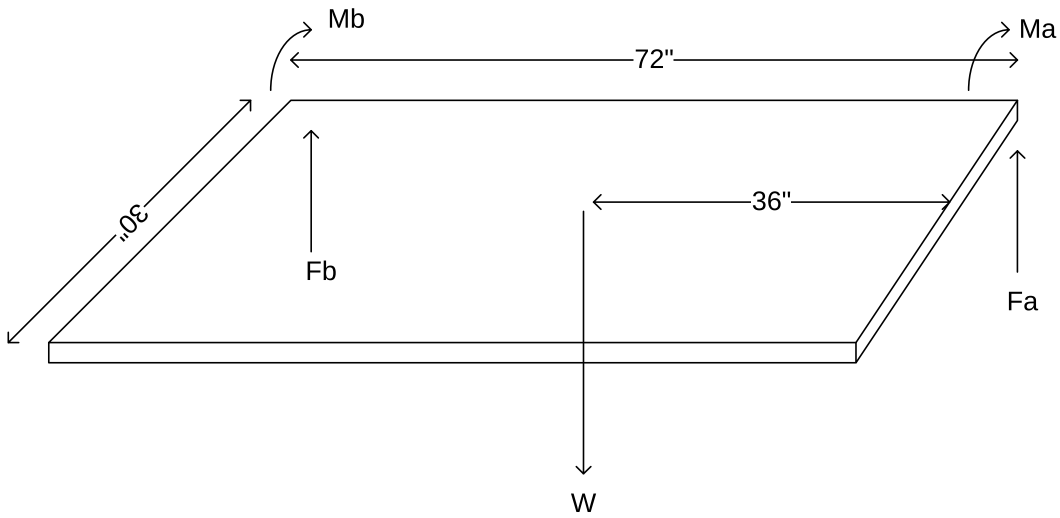

Figure 63: Free Body Diagram of Second Setup

$$\sum M_{AB} = 0 = 15W - M_A - M_B$$
$$M_A = M_B$$
$$M_A = M_B = 7.5W$$

This setup would be much better than the first configuration, and would most likely be able to raise the table. This would also probably not require a second user to raise the table. There is still the problem of the tabletop not raising evenly, the side without the gas springs would be much lower than the side with the gas springs and would require considerable adjustments prior to use. This could possibly be remedied by applying force to the unsupported side while adjusting. This may be able to be done by one person, but it is again likely that another user would be required. Also, it would cause unnecessary strain to occur at the mounts of the gas springs. So, while this configuration would work it is not the best setup.

The third setup is the best configuration because it allows for the most even distribution of force. The force at the two opposite corners keeps the torque from getting too large and also assures that the table will rise evenly. This can be seen in the following equations.

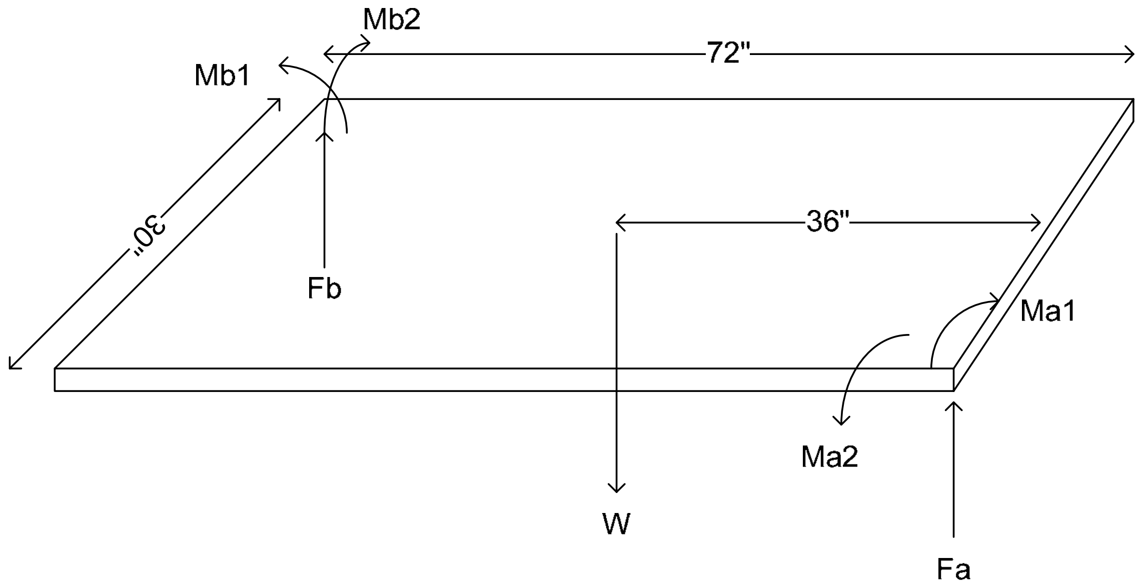

Figure 64: Free Body Diagram of Third Setup

$$\sum M_{A1} = 0 = -36W + M_{A1} + 72F_B$$
$$M_{A1} = 36W - 72F_B$$
$$\sum M_{B1} = 0 = -36W + M_{B1} + 72F_A$$
$$M_{B1} = 36W - 72F_A$$

The moment found in these equations causes rotation over the side edge of the tabletop. This is much lower than the moment found around this axis in the first setup. Also, since the two forces applied by the gas springs equal, the moments will be equal and will cancel each other out. The moment of one side of the table will actually help to hold up the opposite end.

$$\sum M_{A2} = 0 = -15W + M_{A2} + 30F_B$$
$$M_{A1} = 15W - 30F_B$$
$$\sum M_{B2} = 0 = -15W + M_{B2} + 30F_A$$
$$M_{B2} = 15W - 30F_A$$

These moments are around the long sides of the table as in the second setup. These moments are also much smaller than those in the second setup and again cancel each other out. This is obviously the best setup because the gas springs are put under less stress. Also, less force is required from the gas springs to raise the table so the table will rise faster and smoother. Again, the setup should keep the tabletop even as it is adjusted, but if any problems occur one would simply have to raise the corner over the locking aluminum legs before locking them. This is much less additional work than would be required from the other setups.

The final setup adjustment that can be seen from the equations is that as the gas springs are situated more towards the center the torque caused by the unsupported corner is less. So, the gas springs are pushed closer to the center than the actual corner of the tabletop. This can be seen in the following diagram.

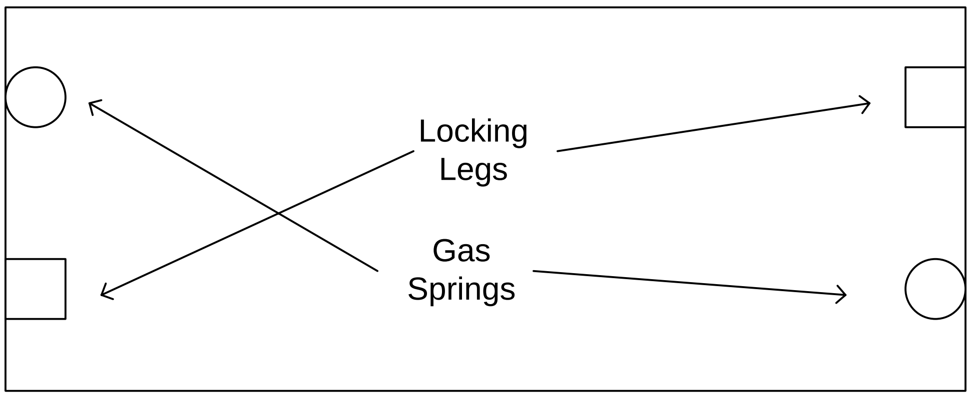

Figure 65: Optimal Setup

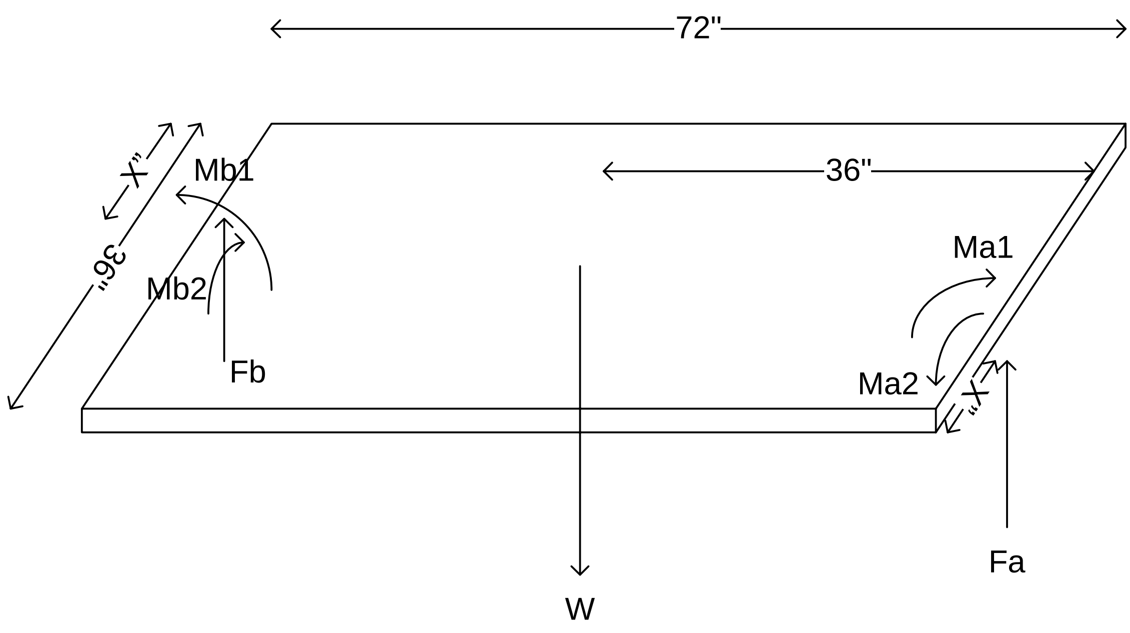

Figure 66: Free Body Diagram of Center

$$\sum M_{A1} = 0 = -36W + M_{A1} + 72F_B$$
$$M_{A1} = 36W - 72F_B = M_{B1}$$
$$\sum M_{A2} = 0 = (15 - X)W + M_{A2} + (30 - 2X)F_B$$
$$M_{A2} = (15 - X)W - (30 - 2X)F_B = M_{B2}$$

If the distance moved in is 8 inches, the forces F_A and F_B are both 14 pounds as specified by the gas springs, and the weight of the tabletop, W, is 25 pounds the change in moments between the third setup and this setup can be examined. For the setup with the legs at the corners, the moments M_{A1} and M_{B1} are the same as those for the setup with the legs moved more to the center. This moment becomes -108 inch-pounds. The negative sign means that the moment actually is in the opposite direction. This makes sense because it is forcing the unsupported side of the table down. For the moments M_{A2} and M_{B2}, the moment is a value of -21 inch-pounds compared to the -45 inch-pounds in the original setup. This decreases the moment around the joint by a factor of ½.

In order to test the optimal positioning of the gas springs it was necessary to construct the table. The only way to determine if the gas springs were going to work is to see if they can actually lift the necessary weight and withstand the torques created by the weight of the tabletop.

2.2.2.7. Mounting the Gas Springs to the Base

The bottom of the gas spring is a threaded piece that is 13 mm long and has a 10x1.5 mm thread. The threaded bottom made it possible to machine a mount to attach to the base. The mount was a simple piece of aluminum with a raised center portion with very thin sections as the sides. The side sections were thin enough for our standard 3/8" screws to work with it, so two 9/32" screw holes were drilled into each side. The center of the mount was 0.7" thick, which was thick enough to screw the entire gas spring into it. A hole was drilled into the center of the mount and threaded to fit the gas spring. A diagram of this mound can be seen below.

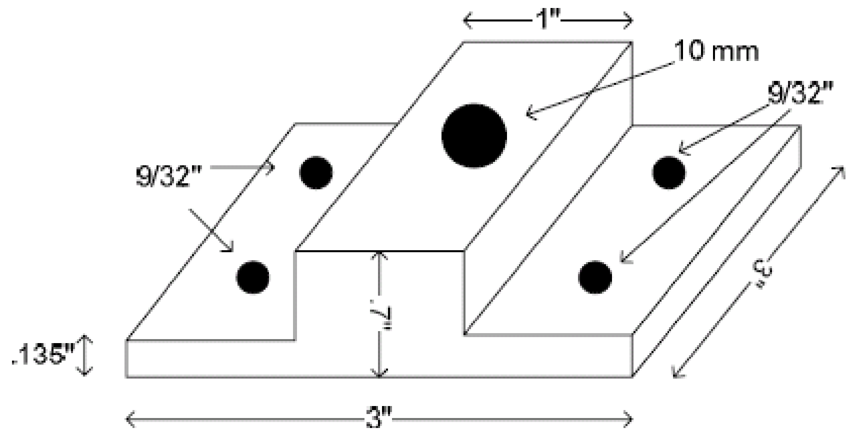

Figure 67: Mount to Base

The screw holes were screwed into the outer two slots of the 1x3" extrusion in the base. The mount is attached in the same way the rest of the extrusions are connected, using t-nuts in the slots. A diagram of this setup can be seen below.

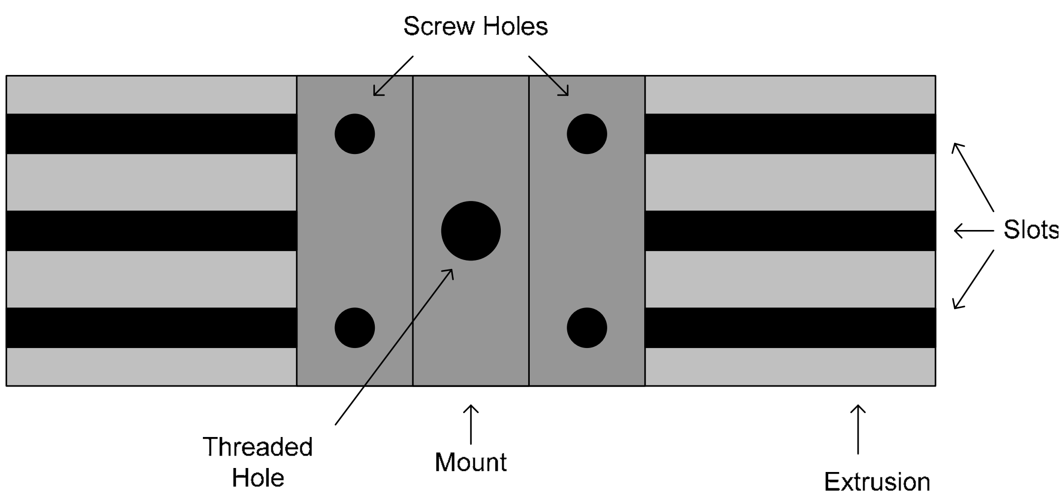

Figure 68: Mount Positioning on Base

The top of the gas spring is not threaded, which posed a problem for mounting. The top of the gas spring is covered by the hydraulic release, so something needed to be done to attach the hydraulic release to the upper framing at these points. The cap of the hydraulic release is made out of aluminum and consists of a loop. In order to mount this, we drilled down through the upper framing and into the cap. We then threaded the cap and attached it to the upper framing using a long screw. This can be seen in the following diagram.

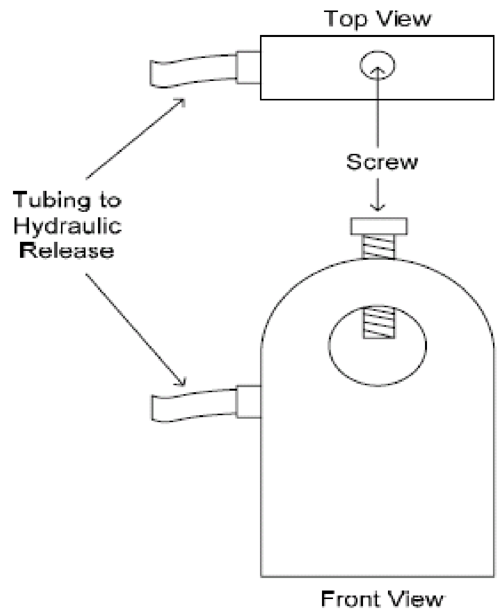

Figure 69: Diagram of Top Gas Spring Attachment

This was a simple attachment that allowed the gas spring to be attached without destroying the cap or making it necessary to device a complicated mount to interact with the loop.

2.2.2.8. Hydraulic Release

The gas springs are controlled using a parallel hydraulic release. This release consists of tubing filled with water. A plunger or button is pressed that causes the water to force in a lever at each gas spring. The lever then disengages the locking mechanism and the gas springs can adjust. The parallel hydraulic release is useful in our table because it allows for both gas springs to be adjusted at the same time using one control button. The tubing had to be long enough to stretch between the sides of the table, there also needed to be enough tubing to then run the release button to one side. A diagram of the release system can be seen below.

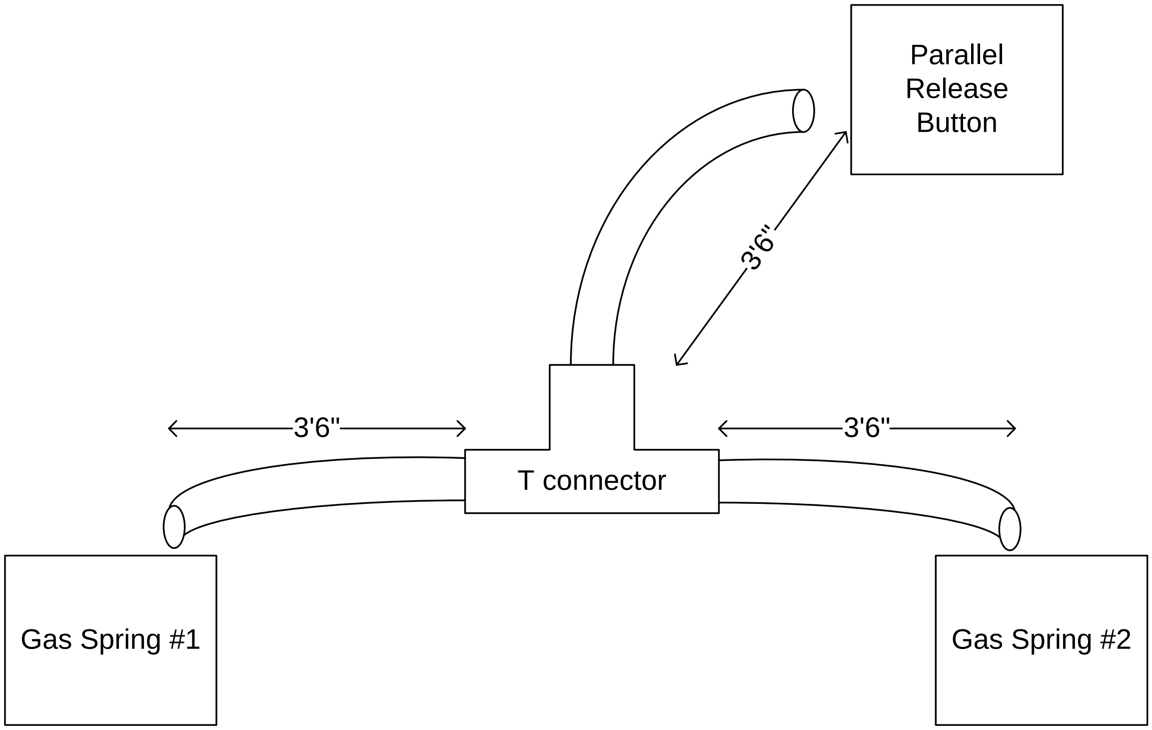

Figure 70: Hydraulic Release

The T connector needs to be situated equidistant from the two gas springs. This means that it must be mounted underneath the center of the tabletop. The tubing then extends to each side of the table where the gas springs are mounted and the third tubing is brought to one side as well. This is so that the release button is out of the way of someone sitting at the table. Also, this allows the user to press the button and adjust one of the sides at the same time. The mounting of the tubing is handled by running it in the grooves of the extrusion used for the upper framing of the table. Slot covers are then placed over the tubing to firmly keep it in the slots. The release handle is attached onto the table framing using two simple mounting plates with a hole to screw into the framing and a hole to run the button through. This is attached far enough from the edge of the table so that it can not be accidentally pushed by someone walking by the table. Also, there are nuts on each side of one of the mounts to keep the button in place. The covering of the button and plunger is threaded, so this keeps the button securely in place. A diagram of this can be seen below.

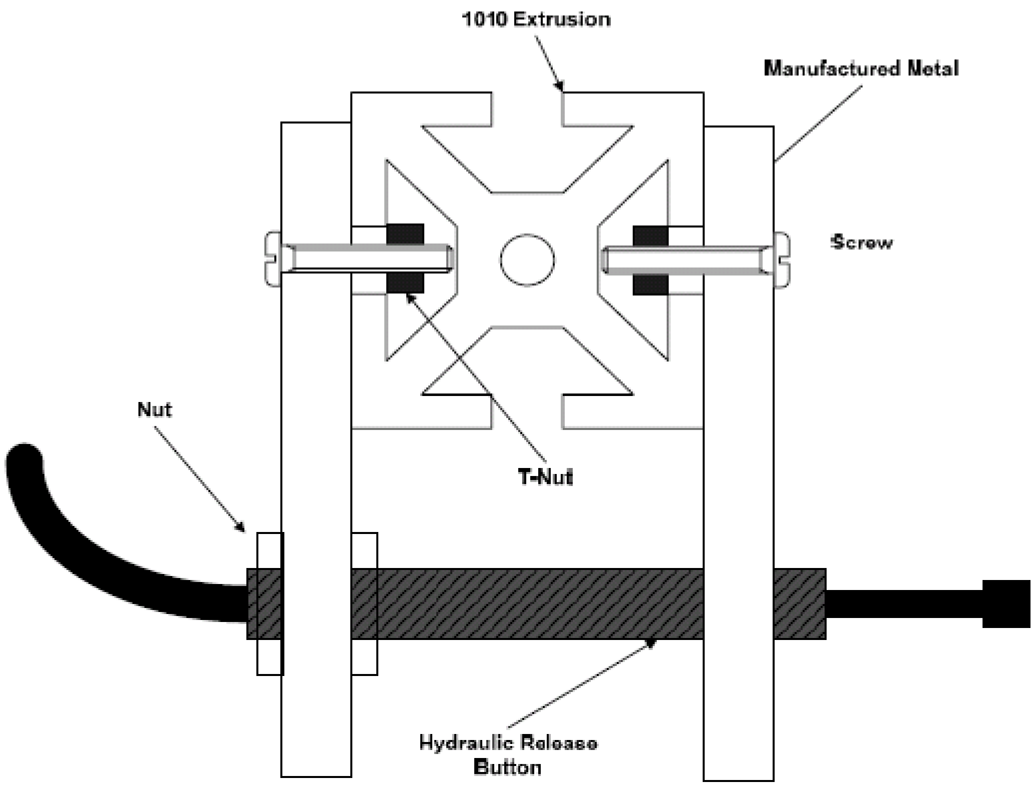

Figure 71: Mounting for Hydraulic Release Button

The main thing that needs to be tested about the hydraulic release system is whether it causes the two gas springs to work at the same rate. The release system screws onto the top of the gas springs and depresses a button on the gas spring when the release button is pushed. Based on the degree in which the release is screwed onto the gas spring the gas spring will adjust at different speeds. If the release is screwed on too far the gas spring will stay engaged at all times, which will make it impossible to lock or stop the gas springs at a desired height. If the release is not screwed on enough the gas springs will never disengage when the release button is pressed. They will stay in a constantly locked state that makes adjustments impossible. To find the perfect positioning of the release on the gas springs it is necessary to screw the release on in different positions and find the optimal one. This position is then marked by placing a nut at that point so that it can be screwed to the exact position in the future. This can be seen in the diagram below.

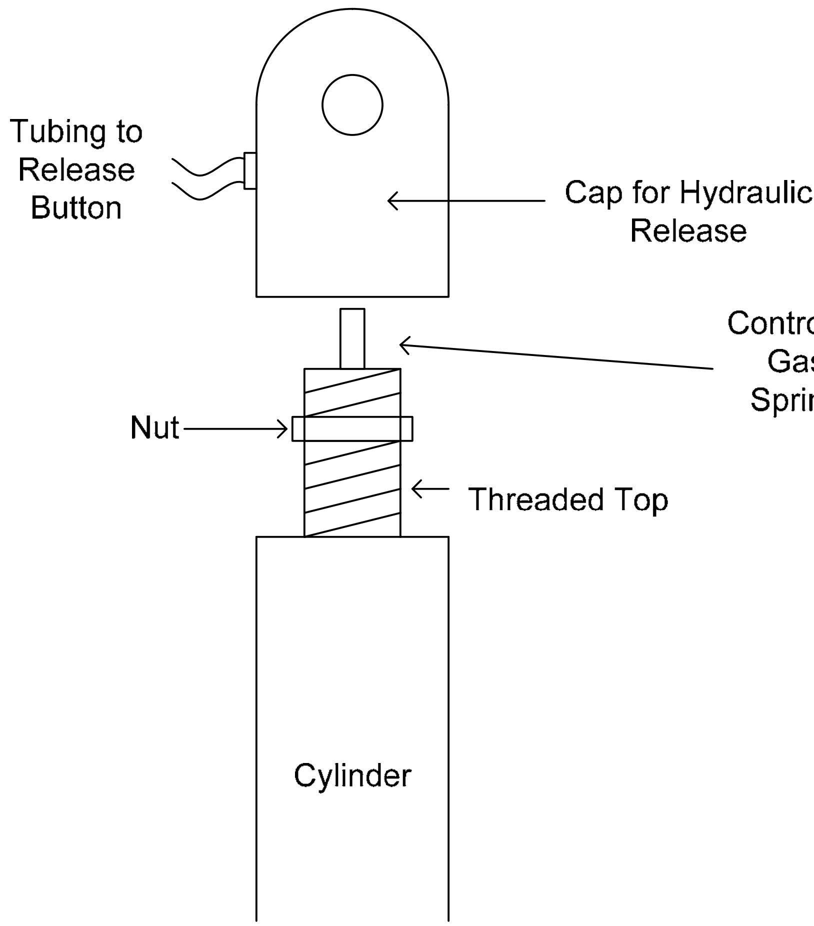

Figure 72: Top of Gas Spring

2.2.2.9. Base

The table base will be a determining factor in the overall stability when the table is on a flat surface. Ideally, it would be easiest to create a base that could run across the ground from one side to the other. This would ensure that the base was totally in line with the orientation of the tabletop. Unfortunately, this base connection could not be made due to the fact that it would impinge upon the leg room of the user. The next best setup was to create two separate bases which would each be the width of the tabletop. The extrusion used for the base is also three times as thick as the extrusion used in the rest of the framing. This extra thickness will greatly help in the stability of the table as a whole. The thicker the base, the harder it will be to twist it off the ground. The dimensions of the 1030 extrusion used for the base can be seen in fig. 11.

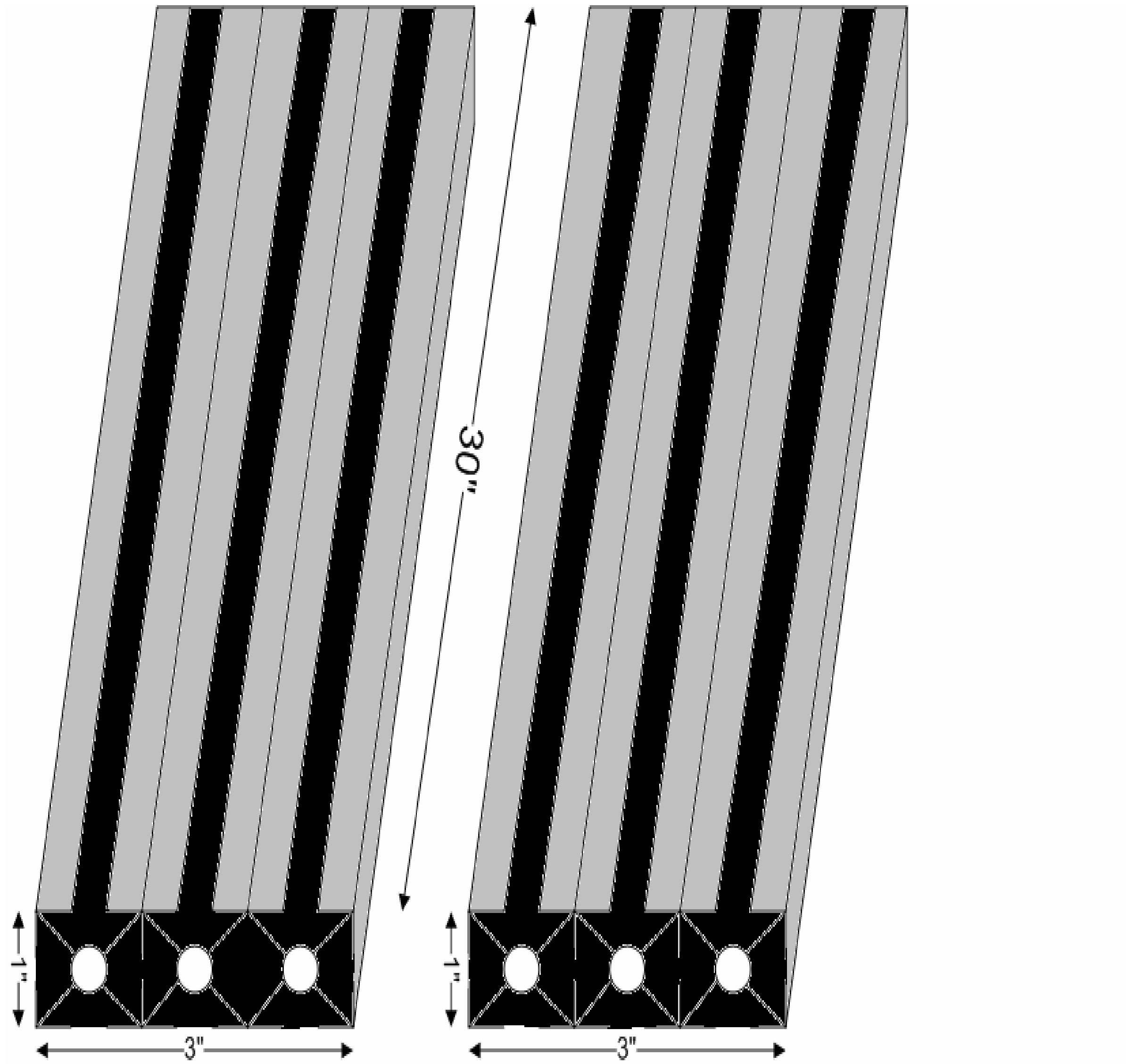

Figure 73: Dimensions of base

This base setup will give the user the maximum amount of leg room needed when drawing. This setup also provides good stability, but it can be improved upon slightly.

This improvement was decided after testing had occurred on the base. This testing involved putting the entire table together. Once the table was put together, force was applied horizontally at one side of the tabletop. This force would cause the two base pieces to sway back and forth since they were each bolted into the sliding legs and gas springs. The setup for this testing can be seen below in Fig. 74. This testing showed that the current base could be slightly more stable for the design that was implemented.

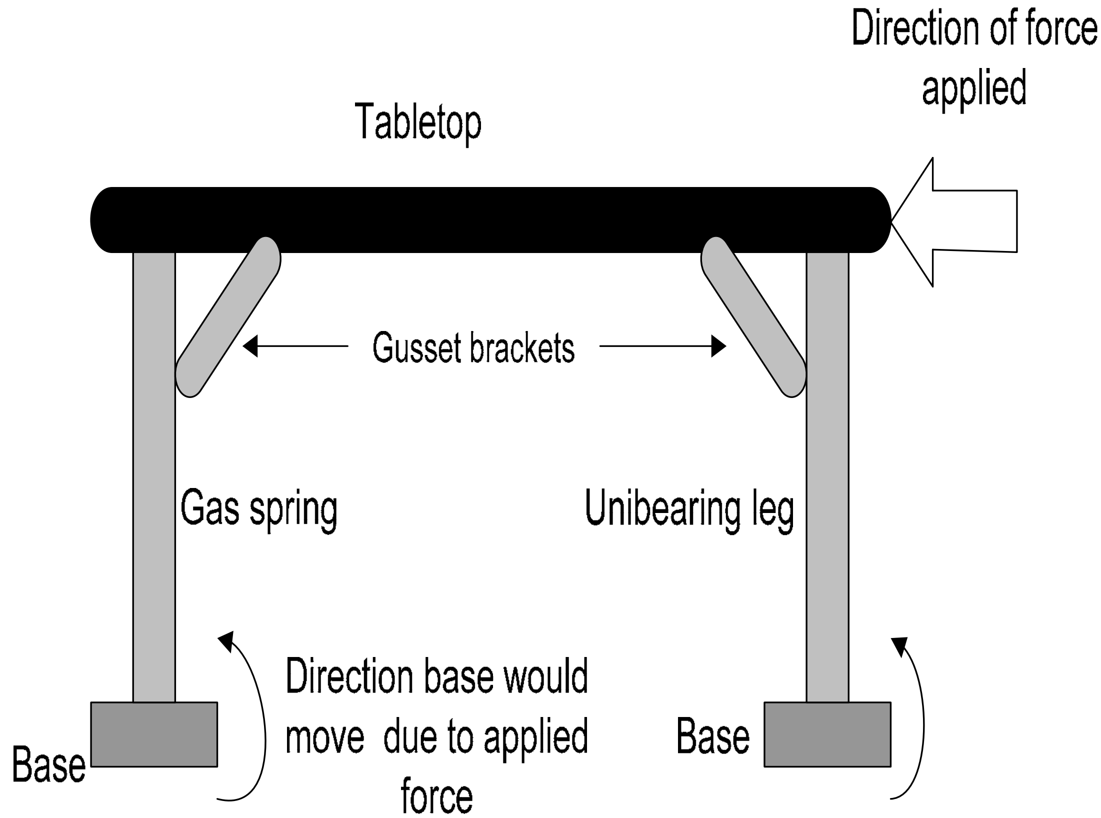

Figure 74: Testing procedure of base

It would be impractical to keep widening the entire length of each base to increase the whole table's stability. Instead, only the ends of the base can be increased in thickness in order to prevent the entire base from wanting to lift off the ground when the table was pushed from the side. This was achieved by purchasing another 1010 extrusion of 30" length. The final schematic of the base can be seen on the following page in Fig. 75.

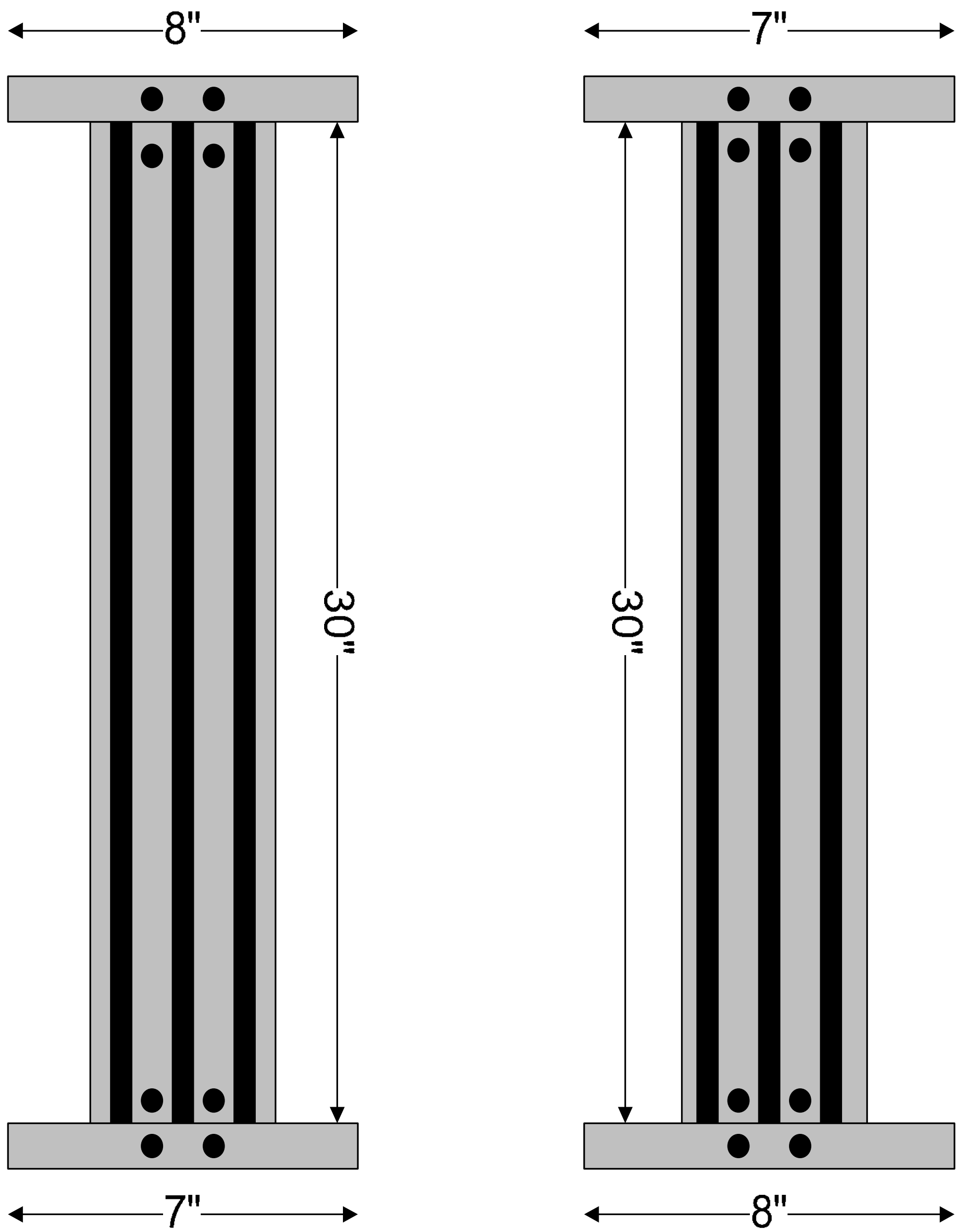

Figure 75: Base with added extrusion on ends

The 30” 1010 extrusion was cut into two sections 7” long, and 2 sections 8” long. These were then placed at each end of the 1030 extrusion. These extra pieces were connected to the base by flat connecting brackets which were manufactured in the machine shop. A schematic of these brackets can be seen in Fig. 76.

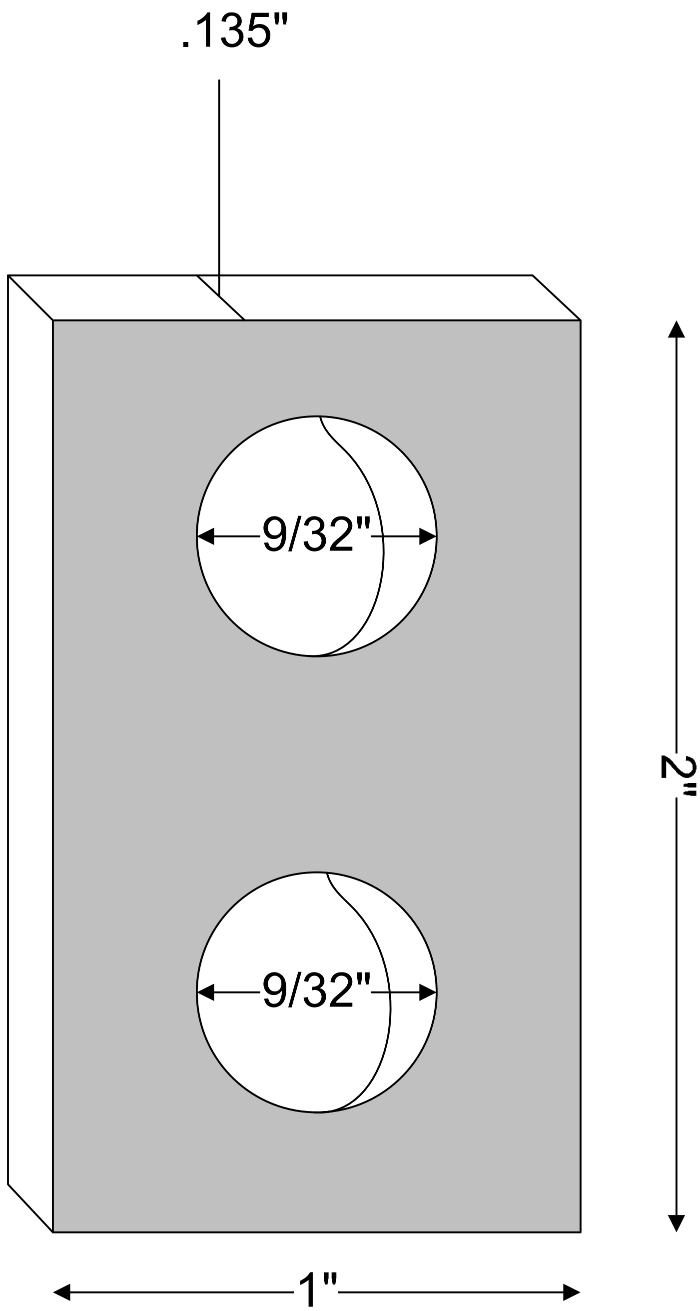

Figure 76: Dimensions of flat mount

2.3. Prototype

The completed table serves as a way for students, who may or may not use a wheelchair, to do artwork at a comfortable height. The table was designed and tailored to a specific clientele. The client company, Passion Works Studio has requested that the art table be designed for its customers who need a reliable and effective place to work and may also have mental or physical disabilities. The people who will be using the table have specific needs and requirements so the table must accommodate such needs. The height adjustment of the built table can accommodate wheelchair bound users. The user can easily wheel underneath the table, with enough leg room, and assistants can lower the table to a specified height.

Description of Prototype

The table is designed for specifically doing art, but can essentially be used for anything. It is specifically designed for doing art because of the smooth tabletop surface. The table also consists of four legs, two of which are gas springs, and the remaining are 8020 unibearing legs. Alike legs are diagonal from each other. The following picture shows the completed table.

Figure 77: Complete Table

Therefore on each end of the table, there is a unibearing on the left, and a gas spring on the right, if one is looking from the outside of the table. It is essential that the users know how to operate both legs so that the table will function properly. Two assistants are necessary to lower the table, but it is designed so that only one person can raise the table. Each side of the table looks like the following, except on the other side of the table, there is no gas spring release button. The following figure accurately depicts the finished table.

Figure 78: Side of the Table

The table therefore operates on the assumption that (1) the gas springs will lock (2) the unibearings will be tightened by the user (3) pushing in the gas spring release button will activate the gas springs which will then push up on the table. If any one of these assumptions is not true, then the functionality of the tabletop is compromised. The gas springs can sometimes become loosened, or if the screw on the top of the gas spring moves, the gas springs can sometimes not lock. This situation is described in more depth in the operations manual. The table also depends on the user because the user should lock the unibearings when it is not desired that the tabletop adjust in height. Both of the handles should be used, as one is not sufficient. When the tabletop needs to be adjusted however, the user must know to loosen the handles. If this does not happen, the tabletop will twist slightly, but in general will not move. Ideally the tabletop should be level. In order to maximize the quality of the artwork that will be done on the tabletop, it should be as level as possible. In order to do this, the user must straighten out the tabletop and make it horizontal before the unibearings are tightened completely. This may mean raising the side of the table that has the unibearing slightly, because it will be this side that is lagging when the table is being raised. A figure level tabletop is depicted in the following. Although the gas spring release button is not mounted in this photograph, it is in the final product.

The frame also adds to the stability of the table. Just as the table is designed to withstand vertical forces it can withstand horizontal jolts without disturbing the artist at work. This solid, sturdy table top will last a longer time because of the integrity of the frame. There are extrusions that connect to the ends of the 1030 extrusion in order to prevent the table from succumbing to the horizontal forces. The 1030 base extrusions were rocking on the floor so these perpendicular 1010 extrusions prevent the table from rocking. There are four, since there are two 1030 extrusion bases and there is a 1010 extrusion on each end of the base.

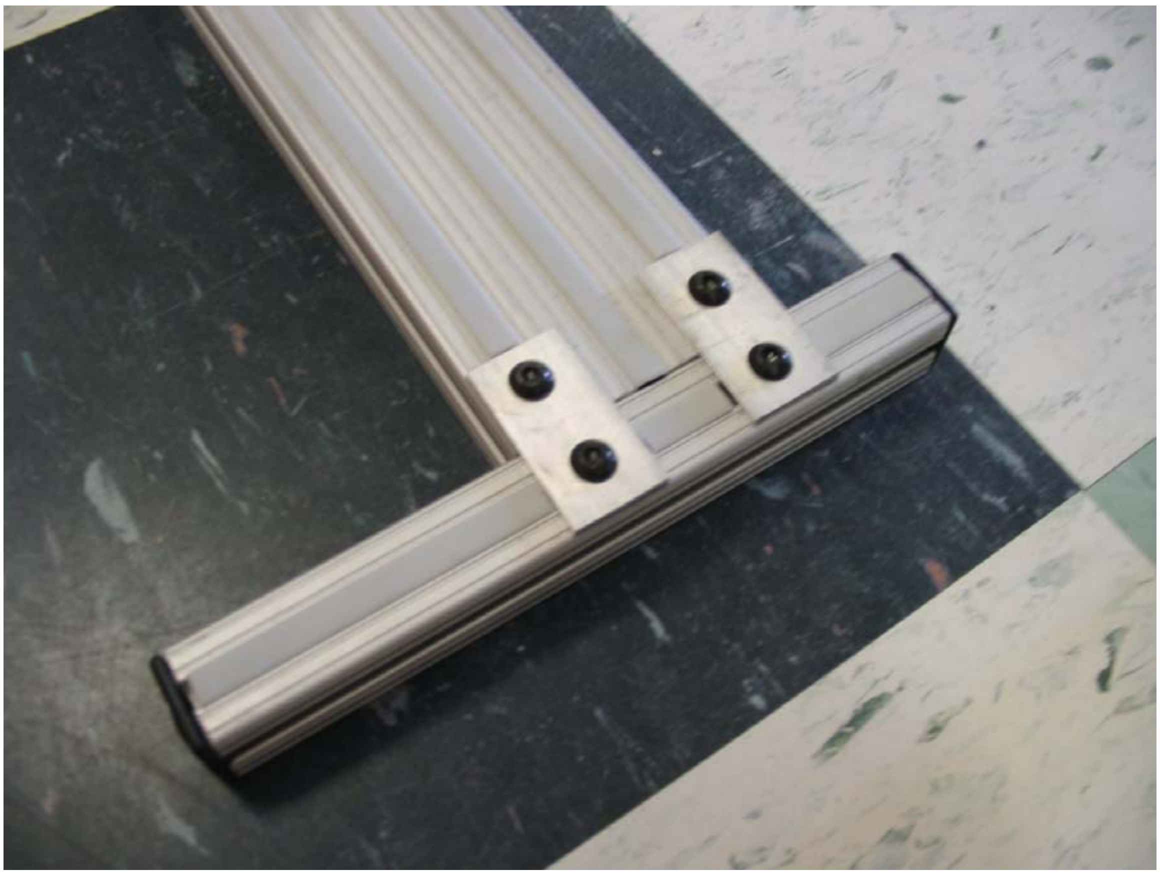

Figure 79: Stability Extensions on the Base Extrusion

The gusset brackets help to prevent rocking as well because it prevents the frame from sliding along the bottom of the tabletop. The gusset bracket was tested later in this section in case it interferes with the arms rests of a wheelchair. It turns out that it does not.

Figure 80: Gusset Bracket

The tabletop itself is highly resistant to scratches because it is made out of plastic. A soap solution could be used for easy cleanup in case of a spill. The tabletop has a smooth surface is ideal for art work. It also has smooth edges and corners that prevent injury from somebody accidentally walking into the tabletop.

Figure 81: Smooth Corners of Tabletop

Figure 82: Smooth Edges of Tabletop

Operation of Prototype

The prototype is extremely simple to use. In order to raise the table, first disengage the breaks on both sliding legs. The breaks on both legs must be disengaged before any height adjustments are made; this is to allow for proper adjustments and to maintain the integrity of the table. A schematic of how the unibearing is loosened appears in the figure below.

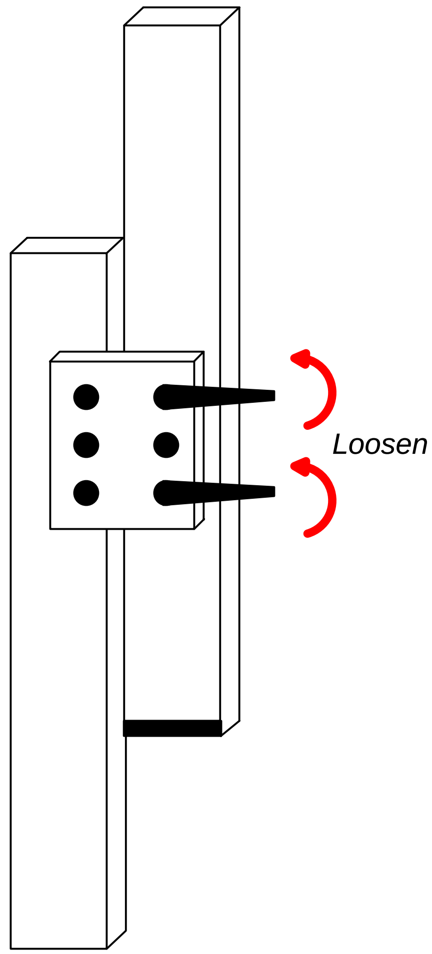

Figure 83: How to loosen the unibearing breaks

Then press and hold release button while table rises. The gas spring release button is on one side of the table. The table only requires one person to be raised. The following figure demonstrates this.

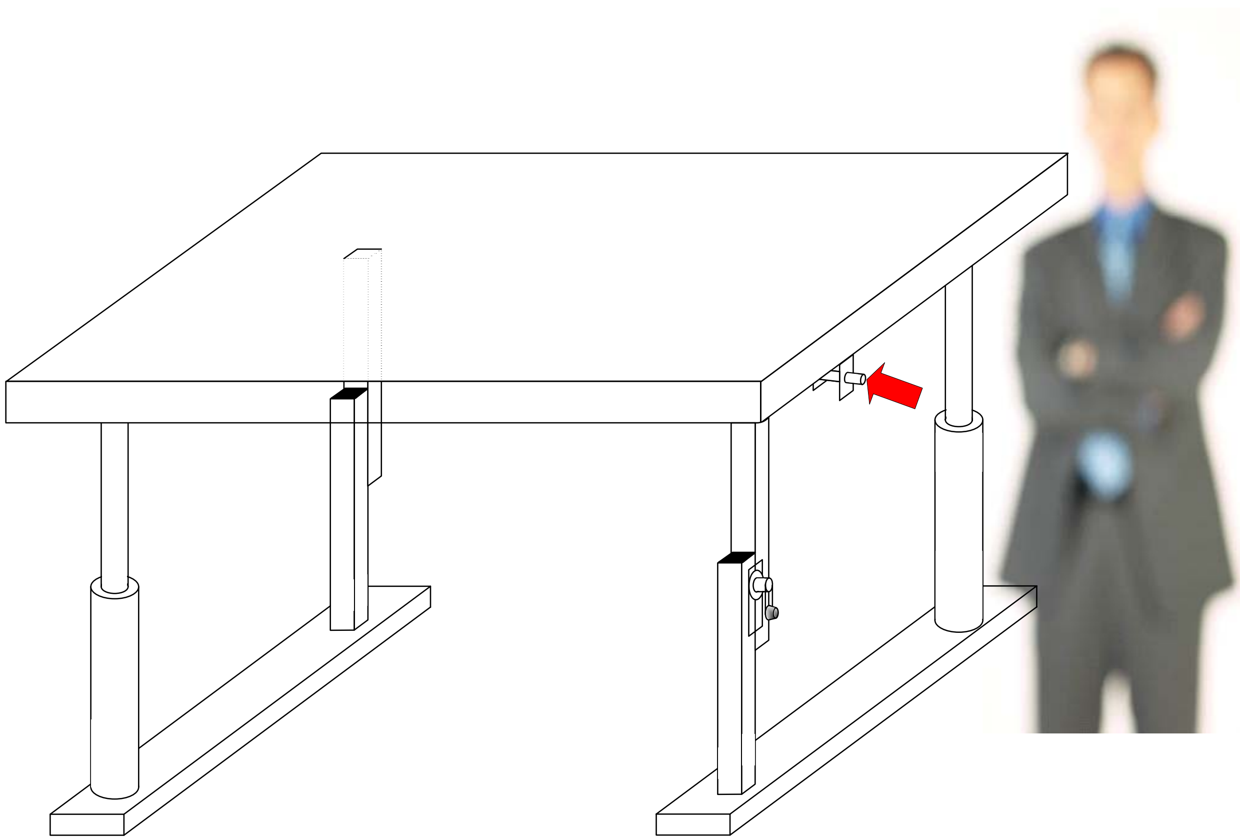

Figure 84: How to Raise Table

By looking at the side of the table, one would notice how the table rises. A rising table appears in the following figure.

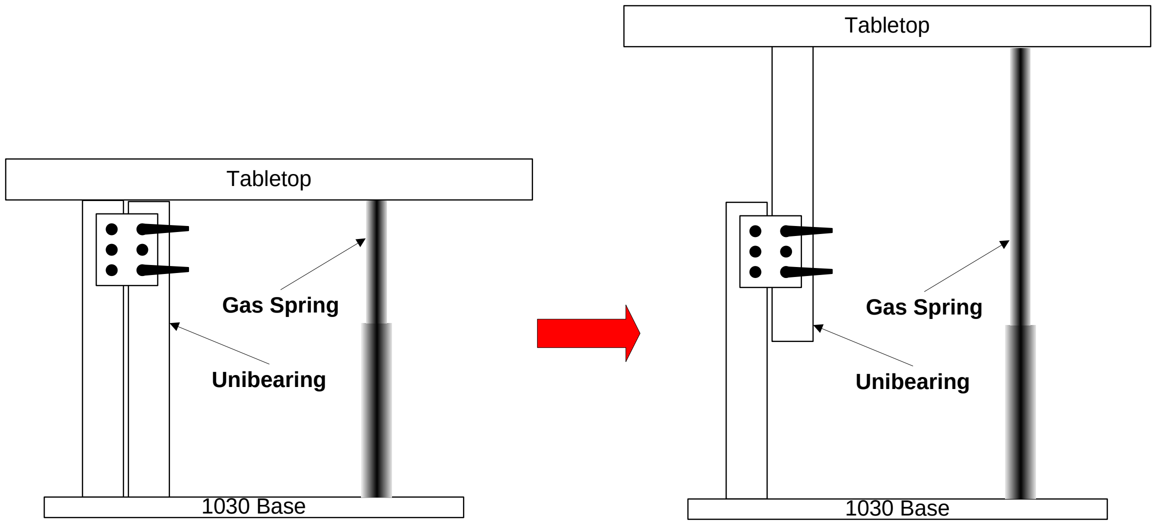

Figure 85: How the table will raise.

Next, pull button towards you to disengage gas springs and stop table when at desired height.

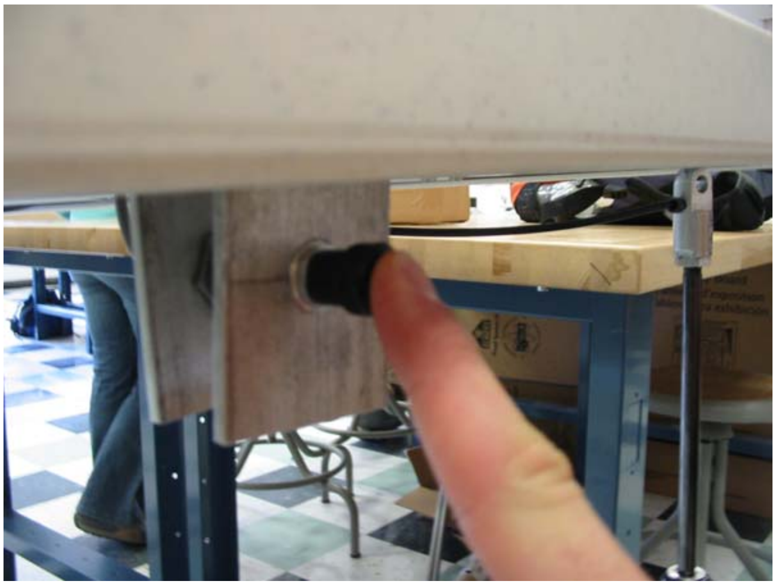

Figure 86: Engaged Button.

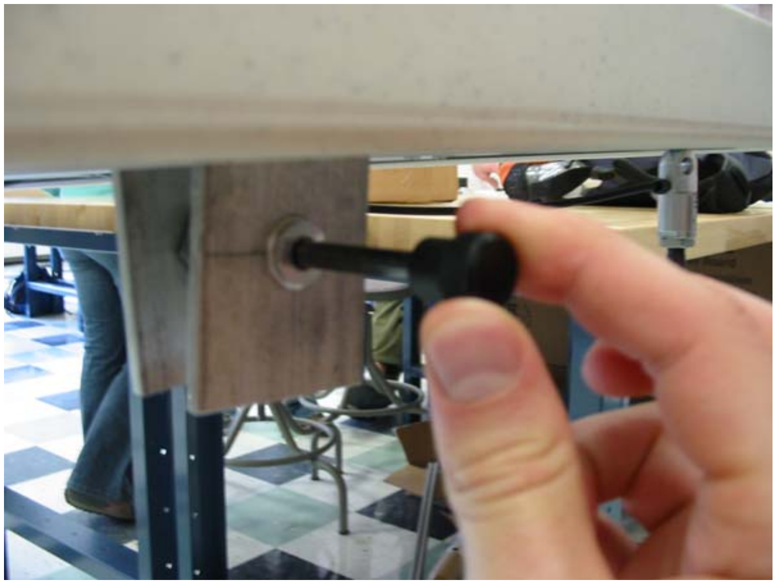

Figure 87: Disengaged Button

The legs of the unibearing may need to be pushed up slightly. Then lock the brakes of both sliding legs. The tabletop should be as level as possible before being used. This will also assure that all the weight is distributed evenly along the table should any heavy weight be placed on the tabletop. The following figure demonstrates how when the table is raised, the side of the tabletop that is supported by the gas spring could be a little higher than the side of the tabletop that is supported by the unibearing. This will not allow for optimal use on the tabletop to do art work. The table will be slightly crooked and therefore the artist will have a poor perspective on his or her work.

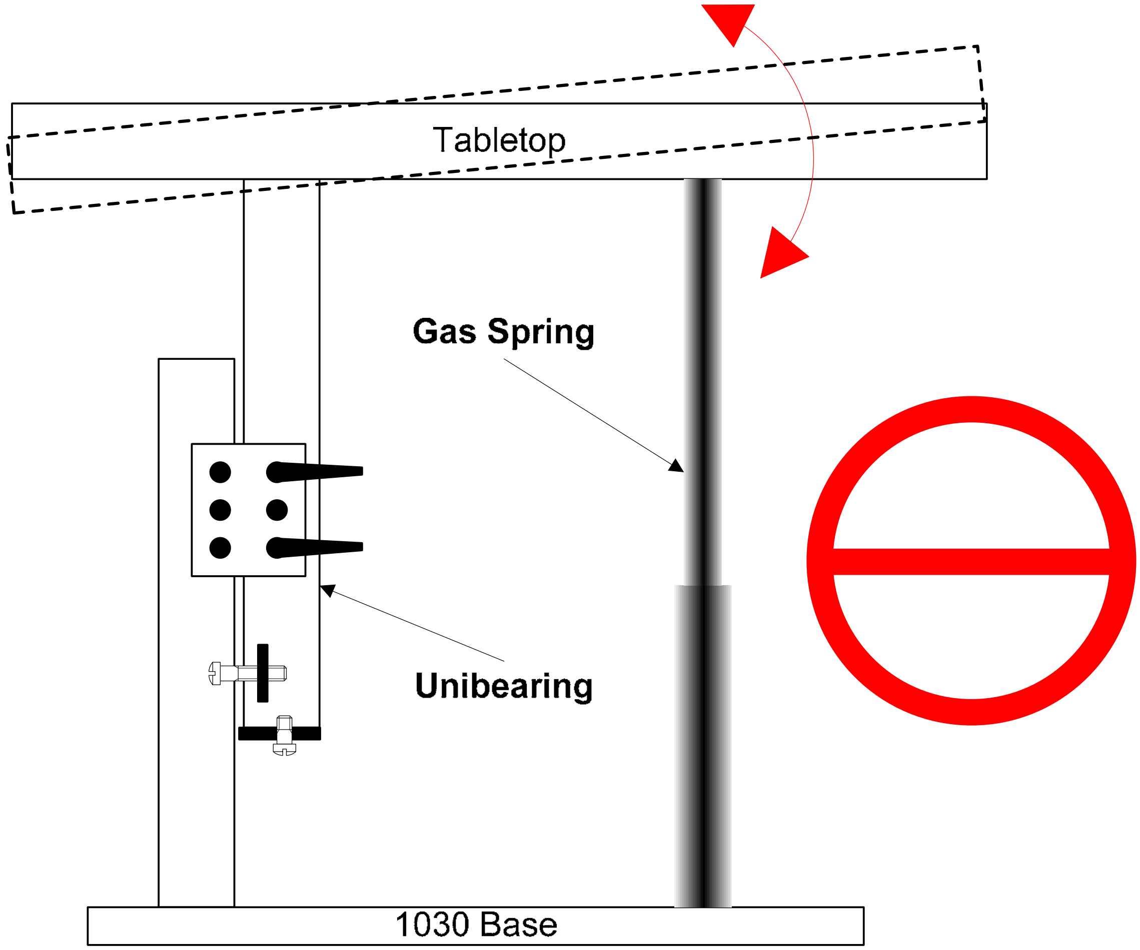

Figure 88: The table can sometimes become slightly crooked, but this problem was fixed
(Note: This diagram exaggerates, and is NOT drawn to scale)

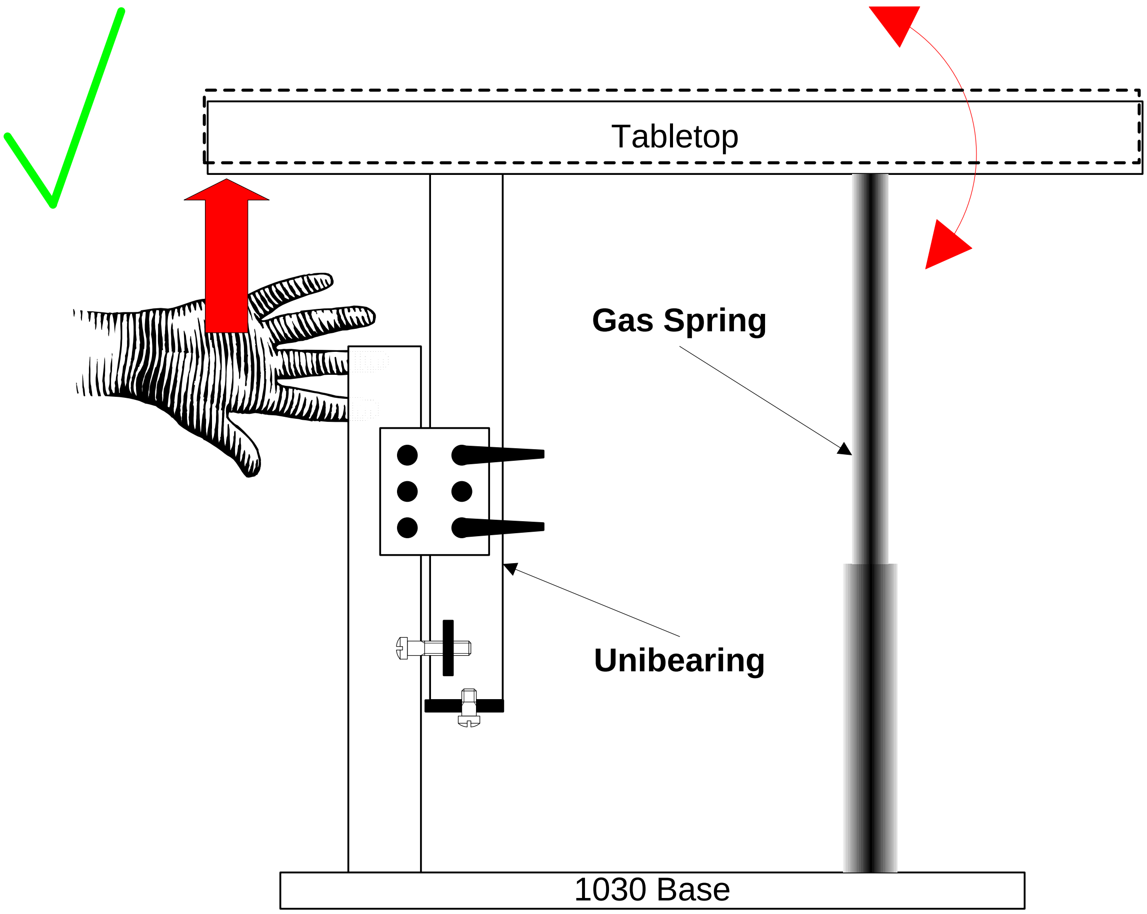

Figure 89: Push up slightly on the left side

Therefore after the tabletop has raised to the desired height, and the gas spring button is disengaged, then the user can slightly lift the left side of the table to make the table completely level. This would require minimal force—it is a matter of lifting that corner of the tabletop, and considering the tabletop weighs 20 pounds, this would be about a four pound force. A picture of how the tabletop should ideally look appears in the following figure. Notice how the left side of the tabletop is the same height off the ground as the right side of the tabletop. The brakes have been locked and the gas spring is disengaged so that they do not create any more vertical forces on the bottom of the tabletop.

Figure 90: The table should be level when in use

Once the tabletop is adjusted to an even height all around (i.e. each corner of the tabletop is the same height), then the unibearings should be locked as described in the unibearing subunit of the optimal design. Although only one tightened handle will prevent the table from raising, only one is not sufficient to prevent the unibearing from moving. The handles should be tightened enough so that they hold the extrusions in place, but not too tight so that the handles break or they cannot be loosened. Sometimes the handles actually hit each other, such as when the top handle is pointing down, and the bottom handle is pointing up. Therefore, one handle should be tightened at a time so that it is out of the way of the other handle. A general schematic appears in the following figure.

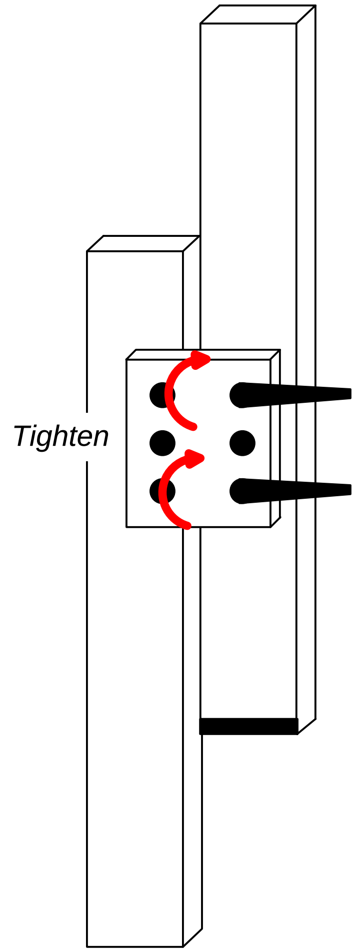

Figure 91: How to tighten the unibearing brakes

It is essential to have the brakes locked during use to ensure the safety of the user and the stability of the table. When locked, the brakes have the ability to hold at least 300 lbs per leg. This locking power ensures that no accidental adjustments can occur to the extent that harm could be inflicted on the user. It is necessary to get a feel for how much the handles can be turned, because sometimes they can be tightened to the point where it is extremely difficult to loosen. Table is ready to be used for numerous activities, at your desired height.

The user can use the table for a multitude of art activities. The following art can be done on the adjustable art table:

- Painting
- Pencil Sketching
- Pencil Shading
- Crayon Drawing
- Dying
- Polishing
- Making Murals

- Sculpting

This is not an exhaustive list of what can be done on the table. It can also be used as a utility table for random chores. It can hold different items easily, granted they do not roll off the tabletop. Once the unibearings are locked and the gas springs are disengaged, the tabletop can hold up to 250 pounds. The tabletop should have nothing on it to be adjusted in height. When the user desires to lower the tabletop, one should first clear any items off the top.

Lowering the table makes the tabletop closer to the ground. Therefore the table will end up at a lower height than when you start adjusting the table. The tabletop can be lowered any amount, from the full adjustment to even a fraction of an inch—there is no one spot that the tabletop has to stay. This is just one of many benefits to the table, because the height can accommodate virtually anybody.

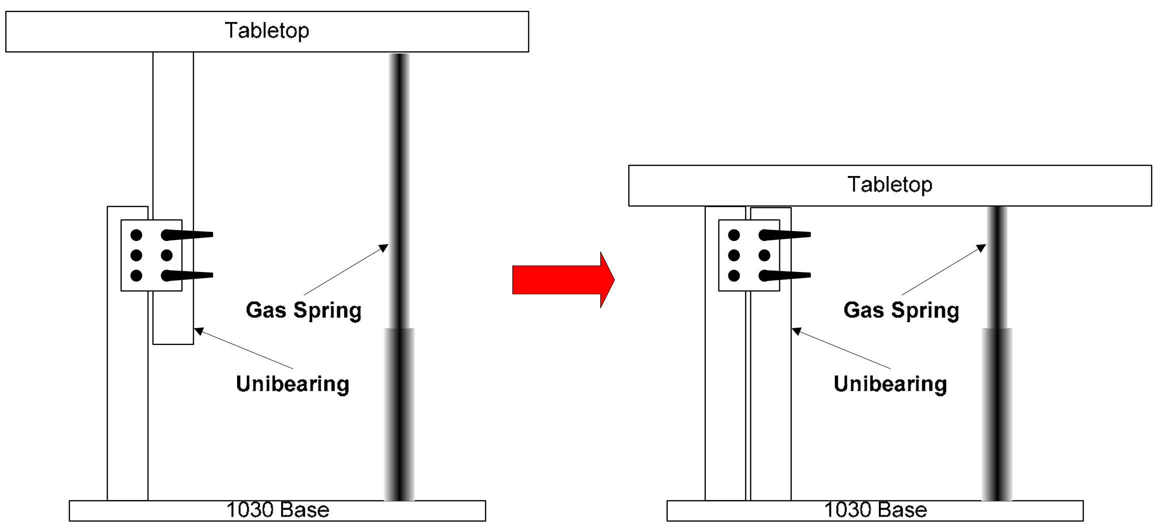

Figure 92: How the table looks when it lowers

To lower the table requires two people: one on each side of the table.
One person should be pushing directly down in the middle of the side of the tabletop, while the other person should be pushing down while pressing in the gas spring release button. A general schematic of where the users should be placing their hands appears in the following figure, as depicted by the red arrows.

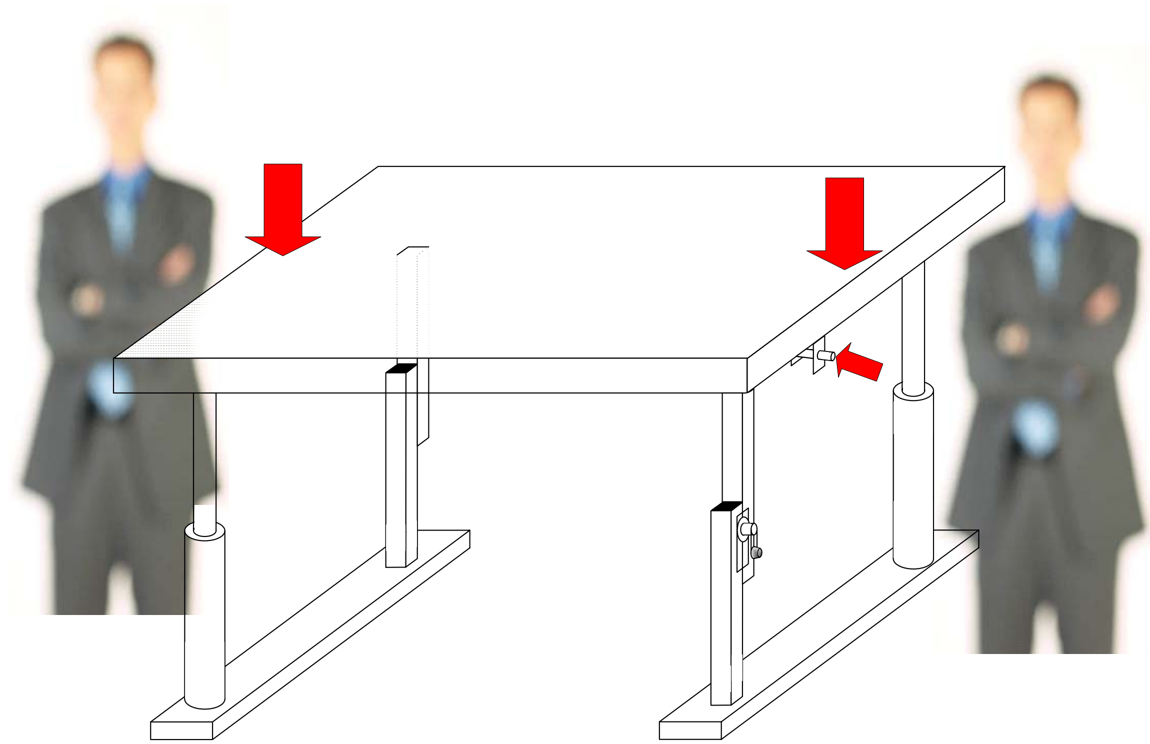

Figure 93: How to lower the table, using two people.

The gas spring release button should be pushed in and disengaged as described previously. If the gas spring release button is pushed in, it is engaged, and if it is pulled out, it is disengaged. When the button is engaged, the gas springs will want to raise up, but it is possible to push them down. When the button is disengaged, the gas springs will not move, and it is impossible (for a human) to push them down. The tabletop should be lowered to the desired height, while being careful not to lower the table on any person or object. Lowering the table onto a person could cause a severe injury. The following figure depicts how the user should *not* do this. Once the tabletop is lowered to the desired height, the gas spring release button should be disengaged so that the gas springs do not push back up after you take your hands off the top of the table. After the gas spring release button is disengaged, the tabletop should be leveled out as described previously. The user could then adjust the corner of the tabletop with the unibearing on one side, and then walk around and adjust the corner of the tabletop with the unibearing on the other side.

Figure 94: Do not lower the tabletop onto another person!

The table is able to withstand vertical forces as well as horizontal jolts without disturbing the artist at work. Not only is the frame be important in making the table more stable, but it serves an important role in the adjustment of the height of the tabletop as well. This solid, sturdy table top will last a longer time because of the integrity of the frame. The tabletop itself is highly resistant to scratches because it is made out of plastic. A soap solution could be used for easy cleanup in case of a spill.

The art table is unlike any other table on the market because it must be height adjustable at all times, not just during the assembly. A quick and easy adjustment allows for multiple users of various sizes to share the same table. Most commercialized tables are not tailored for persons of physical disabilities and who have wheelchairs, so it is difficult for them to use them comfortably. It must also give enough leg room; the legs of the table could prevent the user from pulling all the way up to the table. The table legs are far enough out of the way, but will also provide good enough stability for the table. The adjustable art table is unique because it allows the user to easily move both underneath and above the table so that he or she can do work comfortably.

Prototype Testing

The prototype was first tested with a team member before it was tested with somebody who regularly uses a wheelchair. This was done in order to first smooth out any trivial errors before the real tester comes in. It was shown that a person in a wheelchair could easily fit underneath the tabletop and wheel close enough to it to be comfortable doing work. Neither the gussets nor the table legs were in the way of the wheelchair. The user can roll completely underneath the tabletop if she so chooses.

Figure 95: A user in a wheelchair

Notice that if the height of the tabletop is not the desired height, such as if the tabletop is too low it may hit the arm rests of the wheelchair, or if it is too high, it will just be uncomfortable for the user to use, then the user should modify the table accordingly. If the tabletop is too low, then it should be raised. If it is too high, then it should be lowered. If the tabletop is uneven, then the unibearings could quickly be adjusted to counter this problem. Also, since the legs of the tabletop are out of the way of the wheelchair (they are on the sides of the table) the user can easily wheel underneath the tabletop with no problems. Since the legs are on the sides of the table however, the user cannot wheel from the shorter side of the table, but however must wheel in from the longer side.

The team had a student who uses a wheelchair come in the laboratory to use the table. This was the final testing of the table, and it went very smoothly. The student was able to comfortably use the table at a height that she desired.

Figure 96: Jennifer Using the Table

Figure 97: Another Picture of Jennifer Using the Table

The components of the table were out of the way of the wheelchair. The gussets on the side of the table, although they extend down and out, are still enough into the corner of the table so that they are not in the way. This was not a problem because the team had anticipated this before the gussets were bought and installed. The smaller gussets were bought so that they would not hinder the user too much. Second, they were put in a place that would be out of the way of the user. These two things helped factor into why they were not an issue. The following figure shows how the gusset is out of the way of the wheelchair.

Figure 98: Close-up of Gusset with Handlebar of Wheelchair.

If the studio desires the tabletop to be used for other purposes, the tabletop can be easily adapted. As many as three students who may be using wheelchairs can use the table. The only thing hindering it from more students using the table is the length of the footrests on the wheelchairs themselves. If these foot rests do not extend too far, then four students can use the table at once. The following figure depicts how students with long footrests could be seated at the table to maximize the amount of space that each individual gets.

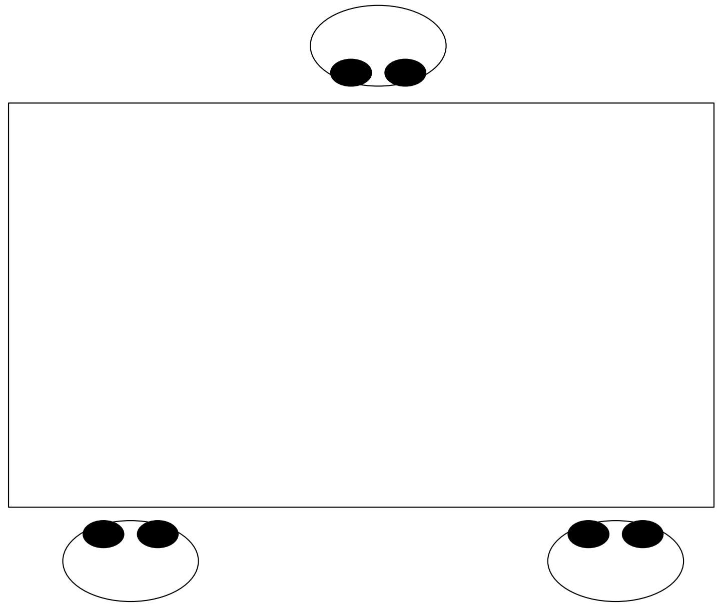

Figure 99: Students who may use wheelchairs with long footrest extensions

If the students have smaller wheelchairs, then up to four students can use the table at once in the following configuration.

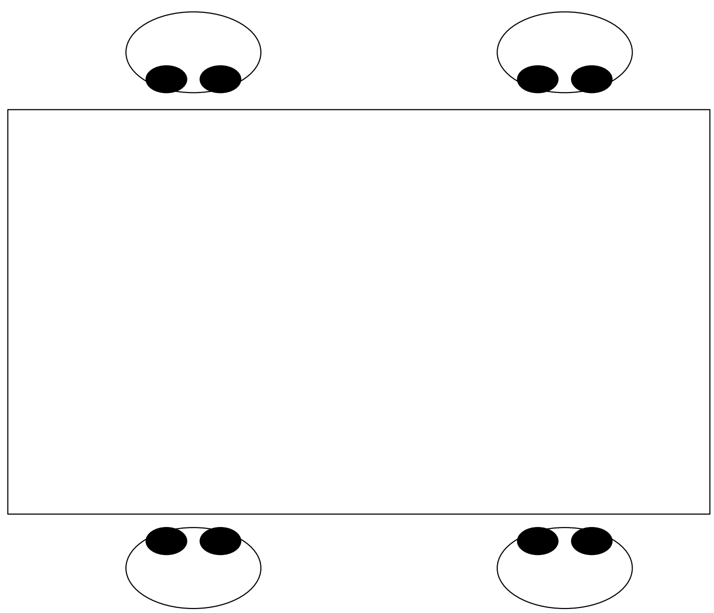

Figure 100: Students who may use small wheelchairs with short footrest extensions

If the users are not in wheelchairs, it is possible to fit up to eight people around the table. This is shown by the following diagram.

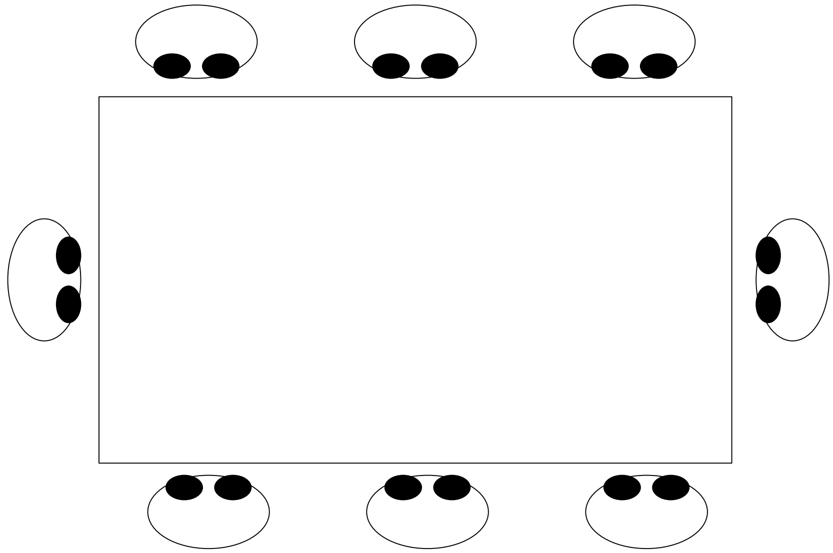

Figure 101: How many people can use the table without wheelchairs

Without a wheelchair, there is more room underneath the table. As already mentioned, the footrests of the wheelchair was the main thing that was preventing more people from using the table. The following figure shows how easy two people can sit across from each other.

Figure 102: Two people can sit across from each other easily

When this many people are using the table, it is more difficult for everyone to have a separate art project. Therefore, the more people that are using the table, the less tabletop room each person has. The fewer the number of people using the table, the more room each person has. The more people that are using the table, then the less room each person has. The tasks that are done on the table heavily depend on how many people are using the table.

Prototype Specifications

The following is an extensive list of specifications that the table has. The list shows how the table has improved from previous NSF designs. It also tells what safety concerns there may be. It gives the specifications of the height adjustment and its performance. It explains the various accessories and uses that the table can be used for, as well as how easily the table can be moved.

- Improvements from the Last Design
  - Stability
  - Non-electric
- Safety Issues
  - Soft, beveled edges for the users
  - Minimal physical effort by the operator to adjust the table
  - The user cannot accidentally knock the table "out of position"
  - Will not collapse under certain limitations
    - Limitations shall be clearly marked
- Height Adjustments
  - High enough for the user to move under the table using a standard size wheel chair or even larger to accommodate a large physique
  - Low enough so that the user can work on the table in a comfortable manner
  - 25-42 inches
  - Does not tilt during this operation
- Performance Unaffected by Environment
  - Liquid spills
  - Stray markings
  - Dust, UV rays
  - Cleaning solutions
  - Regular wear and tear (good longevity) not easily susceptible to scratches
- Accessories
  - Can hold various items:
    - Pencils, pens, paint brushes, paint bottles, chalk, crayons, water bottles
  - The items should be able to remain in the table before during and after the adjustment
- Portability
  - Shall accommodate those who need to move the table
    - Weight of the table should be reasonable
  - Should not roll out of the desired position
  - Size requirements
    - Can be moved easily through standard size doors

        - Not too large to result in unused table space
- Stability
    - Downward weight
    - Side-to-side forces

The team does not anticipate the table to have any problems, but just in case it is always good engineering to explain how these problems can be fixed. The following table contains a list of troubleshooting points.

Table 3: Troubleshooting

Problem	Solution
Table legs squeak when adjusting	Apply a small amount of grease or WD-40 to the area between the metal legs.
Table won't raise on its own	Gently apply pressure at corners (where you would be to lower the table) and help lift the table. This will often happen if the table is overloaded.
Table legs stick or catch when raising	The legs may be slightly out of alignment. Gently tapping or lifting the corner over the affected leg will often fix this.
Table is crooked	If the problem is because the corners over the metal legs are lower than the corners over the gas springs, lift the corners up to make the table level before locking the legs. If the two ends of the table are uneven (the gas springs raised unevenly), press the release button and hold one end down while lifting or lowering the other end until the table is level.
Gas springs continue to rise after button is released.	Press button so gas springs rise to almost full extent. Clamp your right hand on the piston. Your left hand should hold the nut in place just below the upper mount. Once your hands are in place, turn the piston rod clock wise with your right hand about half a turn. Press the button and let the gas springs compress fully. Quickly release the button and check for any slow upward movement of the upper mount. If upward motion is still occurring, the repeat the steps stated above until spring remains locked.

Table 3: Troubleshooting Continued

Gas springs do not rise when button is pressed.	This problem will most likely not be a gas spring problem at all. The nuts below the upper mounts are set in place where there is always a constant force applied to the springs when the button is pressed. This problem would most likely be due to the adjacent locking leg next to it being jammed. This may occur if the table has not been used in awhile. To solve this, see the third situation from the top of the list.
Table stops raising before maximum height of 42”	The gas springs lose some of their strength at their maximum extended length. Sometimes it might be required to help the gas springs on the last one or two inches of extension.

In order to keep the table in the best possible condition, it is a good idea to follow a routine maintenance procedure. This includes making sure screws are tightened, applying a liquid solution to prevent friction, and brushing away any dust or debris that could hinder the performance. The following list is a list of how the user should handle the table.

- Apply a thin coating of generic grease or WD-40 to the sliding leg which attaches at the base as often as necessary. Make sure the table is fully extended when this is performed.

- Wash the tabletop completely with a generic cleaning solution when necessary to ensure the integrity of the tabletop does not decrease over time. This will also ensure that the tabletop stays flat and smooth since previously spilt liquids may induce flaws inside the surface over time.

- Dust and brush away small particles outside the sliding legs as well as the gas springs once a month. This will ensure that no excessive buildup of dust or small particles will occur in between the sliding legs as well as on the gas spring’s sliding pistons. If the debris inside the lubricating fluid of the gas springs is kept to a minimum, the gas springs will always function at an optimal level.

- Check for any loose connections once every couple months. This includes any connection underneath the tabletop as well as between the gas springs and sliding legs with the base. If a connection is loose, your will need either a flat head screw driver or a 5/32” Allen wrench. These tools will tighten any loose screws that come about with the table. This checkup will ensure the table’s stability and proper lifting when in use.

3. Realistic Constraints

There are many constraints that would make production of this table less feasible. The first constraint to consider would be the cost of production. While we had numerous budget setbacks due to design changes, the budget shows that the raw materials for the table would still be close to the allotted budget. Without the parts ordered before the change, the total cost of building the table would have been $712.15. This is still a bit expensive for a relatively simple design. The table would be better off with a better quality tabletop as well, which would cause a considerable increase in the price. The tabletop we used was the best and cheapest we could find that would work with our existing parts. The tabletop needed to weigh close to 28 pounds in order for the gas springs to lift it, which made it impossible to simply find a larger size of the melamine tabletop. A lighter material was required to provide the larger drawing surface, so the lighter and less solid plastic tabletop had to be used. When manufacturing the tables for commercial use it would be possible to find a melamine tabletop that is 6 feet by 3 feet and simply order gas springs that can lift this tabletop's weight. The melamine surface would cost much more than the plastic tabletop of approximately same size, which would again increase the price of the table. The same melamine tabletop sells for $120.40 for a 60" by 37" surface. This is actually smaller than the necessary size and twice as expensive. If this type of tabletop was use, it would actually make the table more worth its cost. This is because the sturdy melamine tabletop would resist bending and is a better surface. This would help to relieve the problems caused by torque around the gas spring mounts and would also ensure that the tabletop rises completely level. The melamine would also be much sturdier under heavy loads such as someone sitting on the table. We would most likely have been able to include this into our budget had we planned the table based on the new specifications from the beginning.

Other than the tabletop issues, it would be very easy to manufacture the table. The construction of the table did not take a very long time, and the majority of the time was spent machining mounts. Programs can be made to automatically machine specific mounts, whether it is corner brackets or specific mounts to attach to the gas springs. This would greatly expedite the manufacturing process, as each mount took an average of one to two hours to make. The rest of the table construction is easily performed and can be done quickly with enough tools and personnel.

Issues concerning the environment are very important to consider in this design process. With regards to the adjustable art table, the environment is not a major factor in the sustainability of the table. This table will be operated and used by our clients indoors. This takes away any potential hazards that the environment can take upon it. The only environment acting on this table will be that of an indoor environment. Even in an indoor environment, this table will undergo some degree of corrosion over time. This can occur due to normal everyday accidents of liquid being spilled on the tabletop all the way down to the base which can eventually lead to pitting corrosion. Pitting corrosion can occur from exposure to water and other liquids the metal comes in contact with. It can also occur over time with regular exposure to oxygen and chloride ions in the atmosphere. As soon is happens, the corrosion rate in the metal will start to increase. Water droplets for example will lie on top of the metal base which cause oxygen depleted zones to form underneath the droplet. The water and oxygen act as the cathodes, while the steel acts as the anode in the corrosion reaction. Over time rust may start to form on the metal surface. The base of the table will be made out of aluminum. This type of metal is generally prone to crevice and bimetallic corrosion. Crevice corrosion may occur in between the surfaces of aluminum on the base and in the legs. The aluminum extrusion used for the base will be cut into three pieces then joined together using brackets. Crevice corrosion may occur at any of those joined points of the aluminum even though it is of the same type of metal. The corrosion occurs due to the restriction one part of a metal which is inside a crevice has as compared to the other which is exposed to a large volume of electrolyte. The electrolyte as mentioned before could be any possible liquid which may creep just outside of the crevice. Ways that this corrosion will be prevented include making sure that there is no dirt or water between the pieces of metal. This could also occur in the slots of the extrusion. If water or another solution sits in the slots it is possible that excessive corrosion could occur if the slots are not cleaned out regularly. By using slot covers we hope to eliminate this threat, which is why it is essential that the slot covers stay in use on the base. Another important aspect concerning the environment is the disposal of the art table. When the art table has served its lifetime, it must be able to be disposed of in a proper manner as to not cause pollution hazards to the environment. Through analysis of the components which will be implemented into the art table, there are no foreseen potential hazards that it will cause to the environment when the table is discarded. The metals as well as the tabletop can be recycled easily.

This adjustable art table poses no direct political issues with the US government itself. The only issue that is any factor in the design of the table is the compliance with the Americans with Disabilities Act. This Act states that sufficient accommodations must be made by a company or employer for anyone which is deemed disabled. This includes a wide range of disabilities ranging from a severe hearing loss to having to use a wheelchair for mobility. The art table being designed is focusing primarily on wheelchair users. Most places have to have certain requirements such as a ramp to meet the needs of wheelchair users. While there is no specific law to be met for the degree of comfort of a table for a wheelchair user, the adjustable table being built will more than comply with any accommodations that would fulfill the laws of the Americans with Disabilities Act. Many people with disabilities which have to use a wheelchair will be very pleased with the design of an easy to use adjustable art table which will accommodate any wheelchair width and height. Now, anyone can enjoy everyday activities such as creating art and work projects with minimal effort. When being analyzed, the government might even consider giving the design a patent due to the fact that it satisfies so many people's needs.

The final issue that must be examined when assessing the table is the sustainability of the table. The table is made out of sturdy materials, so as long as it is kept clean there are no foreseeable problems with sustainability during normal use. If the table is consistently being placed under maximum loads it is possible that the tabletop could warp. This is especially possible if the table is used in an environment that experiences extremely high temperatures. This can easily be fixed by simply ordering a new tabletop and attaching it to the existing frame. Attaching the new tabletop would not require the user to disassemble the frame at all. So, any damage to the tabletop is not a major problem. The gas springs are the main component of the tabletop, and they are said to not discharge or lose pressure over time. If this specification of the gas springs turns out to not be correct, the table will still be useful after the gas springs lose potency. To raise the table it would simply be necessary to apply a small amount of force to help the gas springs. The locking mechanism should be unaffected by any discharging of the gas springs. The rest of the parts are simple parts that can be ordered from the supplier, Air Inc, and easily replaced. The linear bearings and breaks all are attached using a hex nut, and the table does not need to be completely disassembled to replace them.

4. Safety Issues

The prototype created was required to be completely mechanical. This eliminated the use of any electrical components, which would have been the largest safety issue with a project of this nature. Because there are no wires, motors, or other electrical components it is impossible for a user to be electrocuted or shocked by accidentally spilling paint or other liquids into the electrical system. The prototype is also made out of a stable material, so there are no thermal, radiation, or decontamination hazards. Also, since the table is not used in vivo there are no host interactions or biocompatibility issues that can arise.

The issues that will occur with the prototype are based on mechanical failure of the table. If the table were to fail with a person underneath there is a possibility that the person could get trapped underneath. The only way for this to occur would be by a simultaneous failure of the brakes in the aluminum legs and of the locking mechanism in the gas springs, or accidental activation of the gas springs. Because the gas springs are charged to slightly more than the weight of the tabletop, the gas springs will tend to rise when the locking mechanism fails or is accidentally activated. This makes it unlikely that a person can get trapped under the table. The only possible way for the table to lower onto the user is if it is overloaded when the failure occurs. This is dangerous because now the user would be trapped under more weight than the approximately 25 pounds of table. Depending on the load on the tabletop it is possible that a person could be seriously hurt. This is why it is recommended that the table is never sat on or loaded with large amounts of force while in use. This is most likely going to occur by accidental activation of the gas springs, which can be caused by someone pressing the release button when the user is not prepared to adjust the table. In most cases the brakes will be engaged at the time of accidental activation, so no harm will come to the user. These brakes can withstand at least 300 pounds of force, so they will be able to hold a reasonable load up long enough for the user to get out from under the table or for someone to lock the gas springs.

Another possible hazard is tripping over the legs of the table. The legs do not extend past the edge of the tabletop, so they do not pose a very large hazard but it is still possible to trip over them. To make this less dangerous, the tabletop edges are all rounded plastic. This makes it impossible to cut ones self on the tabletop. It is also possible that someone could pinch their skin in between the two separate pieces of the aluminum leg. This is very unlikely due to the positioning of the legs compared to the user, but it must be noted. Very little injury should occur due to this, but mild cuts and abrasions can occur.

The final possible safety issue is an issue of a chemical hazard. This is due to the oil used in the gas springs. A small amount of the oil leaks out if the table is left upside down or if the gas springs were to be cracked. This is basic oil, but it should not be ingested or applied on delicate bodily surfaces, such as the eyes. The cracking of the gas springs creates a more substantial problem. The nitrogen gas is kept under pressure, which could be a possible hazard as the gas escapes from the broken cylinder. Since the nitrogen is kept at a fairly low pressure, 20.6 psi, this should not be a very large threat. It will however require substantial expenses and hours of work to repair the table.

5. Impact of Engineering Solutions

<u>Global</u>

Engineering solutions help companies around the globe create more efficient products at a reasonable price for the consumer. This was the main objective for the group's design.A lot of research was performed to see what other engineers around the globe had come up with for a similar design which the group was going to try and improve upon. In order for the group to successfully come up with an optimal design, many basic engineering concepts were taken into account. For example, certain dimensions had to be closely analyzed for the proper conversions between US and metric units. Even though metric units are used more on the global scale, the group decided to keep dimensions in SI units to keep things simple. Since just one set of units was decided upon, there would be no room for small errors to occur with converting different units multiple times throughout the duration of the design process.

The group worked very hard on making the table unique in its own ways. From a global perspective, designs should always be built with the thought in mind of there always being the possibility for a patent. Also, in order to complete a design, it sometimes takes some help from some parts of the globe. In the group's design, the gas springs came from Germany instead of the United States. Even though the shipping and cost would be cheaper if purchased in the United States, it was still the better choice to purchase the gas springs from over seas in order to obtain their desired functions. This was a prime example of how the group used the global engineering market in the fabrication of the final product.

<u>Economics</u>

When dealing with economics, engineers try and come up efficient ways to reduce the costs of fabricating a particular product. Ideally, a solutions engineer wants their product to be cost efficient for the average consumer. If the engineer produces a successfully working product at a cheap cost, the product will be very successful in the economical world. Also, the product must be easy to make over a period of time. In order to maximize profits, the product should be able to be mass produced on a large scale. All of the costs to mass produce a particular product should be within the limits of expenditures for the company.

In designing our table, the group was allotted a budget which could not be exceeded. This initial limit on spending costs helped the group produce a table that would be soundly economically priced for the average consumer. A large amount of research was performed in order to find components from retailers at reasonable prices. These components still had to meet the group's specifications at the same time. The budget started to become very small towards the end of the design. This required the group to go about and ask other groups for spare parts. Any item that would keep the design within budget was never overlooked. By the end of the design, the group had only exceeded the budget by less than 10 percent. This was still very economical considering that the design process did not go as smoothly as expected.

Environmental

Environmental factors constantly come into play when a design is manufactured. A company ultimately wants a product that will not be hazardous to the environment over time. In the group's design, there was not much impact from the environment that had to be taken into account. The group's design would be used indoors at all times. This would keep all aspects of the design directly away from the environment. There was also not any components in the design that would do harm to the environment in any way. Some engineered products need a lot of natural resources from the environment. These resources are constantly being depleted with higher production rates. The tabletop is made of plastic resin, and the frame is made of aluminum. The amounts of these resources that are available were hardly affected by the design of the table. This table has an all around low engineering impact on the environment.

Social

Engineering practices constantly become affected in terms of social contexts. Much of this social input occurs before the actual product is put together. When a product is being designed, it is usually designed with aim at a particular group of people. In many cases, these people want to know how the design is coming along before it is finished, so they can get an idea of what to expect. The main impact of this social context is proper communication between the manufacturers and the client.

When the group was designing the table, a drastic change was made in the project about four weeks into the project. Apparently, the group's client was under the impression that the group was going to produce a different design than what was actually being designed. This required the group to make dramatic changes to the design. Even though it would have been easy for the group to just keep the original design, this was not feasible because the ultimate goal of the design process is to have a satisfied client. If one potential client is not satisfied with a product, this may mean that many potential others will not be satisfied as well.

It is always important to have a very versatile design. With this type of design, different types of clients can use it. This could increase the demand for a particular product, which can ultimately increase the income for a company. The group's table can not only be efficient for wheelchair users, but for anyone that wishes to use an easy to adjust table. In terms of social context, there has been a large impact on the design. A final product was engineered that could possibly satisfy many people's needed anywhere around the world.

6. Life-Long Learning

Life-long learning encompasses a wide variety of things. There are numerous amounts of definitions one could use to define the process of life-long learning. An example of a very general definition would say that life-long learning is a continuum of the learning process which takes place at all levels in a formal, non-formal, and informal environment using various modalities such as distance learning and conventional learning. This definition is very accurate as well as very broad. It is not easy to try to sum up what life long learning actually is in a single definition. There are many different aspects of learning which life long-learning actually entails.

This design process has put forth various types of techniques which were learned over two semesters. Before designing this table, the group had not taken on a task of this magnitude before. There were many intricate steps which had to be taken in order to successfully complete the design. The process of formality was one of the biggest techniques acquired in this design process. Much research was needed in order to find out different information that was out on the market dealing with the group's design. The group needed to find out what it was competing against. When in the real world, this is how the design process begins. The group needed to make sure that the design was unique and of their own thoughts. Before this could be thought up, a patent research was conducted to see what other designs were created in the past. This required methods of searching through thousands of US patents. This will be a very crucial technique when someone is out designing in the job markets.

Another technique learned in this design process was the analysis behind all of the parts to the design. In order to create a design that functions properly, the design must be broken down into its smallest components and analyzed completely. This is where directions, speeds, and dimensions come into play. This may seem like a very tedious process, but it is necessary to ensure that everything will work as stated for a particular design. By following this method, the group's design worked as stated with only some minor tweaking to get it where it was desired to be. The group also learned that any design stated on paper will never go as smoothly as it should go when it is actually constructed. No matter how many factors that can be thought up, there are always more that come into play when it is least expected. The group learned about this situation at multiple stages in the fabrication process of the design.

The last major technique learned was the testing procedures of each component as well as the final product. This was not just a one time test on each component. This product testing was very intricate and had to cover all of the possible situations the design would possibly encounter throughout its functional life. A product failing is about the worst situation that could happen for a design team. Without extensive product testing, this product failure may become a reality for some people. This type of testing includes trials from potential clients themselves, as well as other outside sources that may come across the design. This testing is also very important because it can detect product failure in a stage where it can still be redeveloped. This time allowed for the redevelopment of a design is very important in terms of specific deadlines that a design must be ready by. If testing on a product is completed too late, there may not be enough time to fix and analyze any problems that may have occurred in the testing procedure.

7. Budget

Table 4: Budget

Part	Manufacturer	Quantity	Total Cost
Original Tabletop	Officemax	1	$78.72
Locking Gas Spring	Easylift of America	2	$194.06
Parallel Hydraulic Release	Easylift of America	1	$113.45
Shipping	Easylift of America	1	$13.88
Handle (not used but purchase for design prior to changes)	MSC Industrial Supplies	1	$21.86
1” by 1” Aluminum Extrusion	Air Inc	249”	$55.99
1” by 3” Aluminum Extrusion	Air Inc	62”	$32.24
New Tabletop	Staples	1	$64.99
Linear Bearings	Air Inc	2	$32.00
Brakes	Air Inc	4	$36.20
Gussets	Home Depot	2	$15.00
Brackets	Air Inc	18	$58.30
Slot Covers	Air Inc	576”	$26.00
End Caps	Air Inc	6	$7.40
Screws and T-nuts	Air Inc	100	$29.00
Shipping and Handling	Air Inc		$33.64
Total			$812.73

8. Team Members Contributions to the Project

8.1. Bruce Bassi

Bruce's main focus was on the unibearing adjustment mechanism. Upon their arrival from the 8020, it was Bruce's responsibility to inspect the shipment to make sure that everything was correct. Then there was a problem with one of the handles on the unibearing and so Bruce had to fix this too. It was necessary to first figure out the optimal placement of the unibearings, and to figure out the best configuration for them. The placement, referring to where on the table they should be placed, makes a big difference in the performance of the height adjustment. The configuration of the unibearing (how the unibearing is oriented to the table—whether the handles were facing in or facing out) can be in important to the aesthetics of the table. Once all these decisions were made, it was necessary assemble the piece of the unibearing together and then eventually connect them all to the table. The unibearings had to be fine-tuned because sometimes when the table did not raise, it depended on the positioning of the unibearing. Once the unibearing was moved around some, the table raised much better. Although it was Bruce's job to work on the unibearings, Bruce received plenty of input from the other team members. Likewise, Bruce also helped and gave advice to the team about their parts.

8.2. Kristen Haldeman

Kristen focused on the gas springs for the majority of the project. She was in charge of ordering the springs and staying in contact with the representative from Easylift. This included tracking the parts and changing the order when the specifications changed. Kristen also determined the best ways to mount the gas springs to the framing. She determined that the best mount for the bottom of the gas springs would be a threaded hole surrounded by holes to put the screws through. This task took a lot of time to machine two mounts and to determine the exact sizes necessary. Kristen also machined the mounts to the upper framing. This was done by drilling into the hydraulic release. Kristen then drilled through the upper framing to screw directly into the release. Kristen also spent a lot of time testing the gas springs. This required her to adjust the attachment of the hydraulic release so that both gas springs adjusted at the same rate. In addition to this work, Kristen machined two mounts to hold up the release button for the hydraulic release. These mounts were designed to screw into the sides of the upper framing. The mounts had a hole through them to feed the release button. Overall, Kristen did a lot of work in the machine shop designing and building the necessary mounts to attach the gas springs.

8.3. Richard Sierra

During the course of this design, Richard was mainly in charge of the tabletop and the framing setup. Richard had originally found a tabletop from Officemax which had been shipped over the winter break. Unfortunately, the design changed due to new client specifications, and a new tabletop had to be found. Richard ended finding a tabletop from staples which was very light and of correct specifications for the client. With this new tabletop, Richard had to design a whole new framing setup. The framing had to be very sturdy, yet allow for enough leg room for multiple people to use the table at the same time. Richard performed some research into frame setups and came up with a blue print for a frame design for the table. The frame had to incorporate the tabletop, gas springs, and unibearing legs together in a secure manner. Since more framing was needed in this new design, Richard decided to go with aluminum 80/20 extrusions. These extrusions are light, strong, and easily put together. Richard also was responsible for keeping track of all the screws and nuts the group had at all times. Richard did have to run out to the hardware store a few times in order to get some reinforced screws for bolting the tabletop to the upper framing. Richard also decided to leave the steel bars underneath the tabletop that had originally come with it. This prevented the tabletop from trying to torque when it was being raised. Richard stabilized the base of the table by adding extra pieces of extrusion onto each of the four ends of the base. This prevented the base from wanting to lift off the ground when the table was pushed from the side. All together, the tabletop and framing turned out to be very efficient for proper function of the table

9. Conclusion

The table is specifically designed for doing art work but as your needs change this table could be an all-purpose utility table. Its large size and smooth surface make it ideal for any application. The highlight feature however is the height adjustment which allows the table to adjust to any size wheelchair. Anybody can raise the table because it only needs one person. Once the table is set to the desired height, the user can seat himself nice and close and focus on art work with no worries. There is plenty of space for about three people if the artists happen to be using wheelchairs. With no wheelchairs, as many as eight people can use the table.

The table meets the client's specifications about being a sturdy non-electric, mechanical table. It improves upon previous year's designs because (1) it is not made out of PVC and more stable, (2) it does not require electricity, and (3) it allows for more leg room. All of these changes have come together to make an excellent table for artistic use.

10. References

1. All photographs referenced in the Introduction are taken from:
http://nsf-pad.bme.uconn.edu

2. The schematics in Table 1 are taken from:
NookIndustries.com

3. Figure 11 was adapted from the following website:
http://www.closet-masters.com/Ergonomics_SF/Height_adjustable_tables/Free_standing_ATS_specifications.htm

4. Table 2 and Figure 14 were taken from:
www.EasyLiftSprings.com, which is made by Easy Lift of North America, 2004.

11. Acknowledgements

1. Professor Mei Wei
2. Christopher Liebler
3. Jeff Malash
4. Richard Bonazza
5. Boston Gears
6. Tryston Parker

12. Appendix

Appendix Figure 1: Binghamton University Art Table

Appendix Figure 2: University of Connecticut Art Table

Appendix Figure 3: Balt Easy Art Table

Appendix Figure 4: Debcor Art Table

Appendix Figure 5: Closet Masters Art Table